(NASA-CR-160956) MANNED GEOSYNCHRONOUS MISSION REQUIREMENTS AND SYSTEM ANALYSIS STUDY EXTENSION. MANNED ORBITAL TRANSFER VEHICLE (MOTV) CAPABILITIES HANDBOOK AND USER GUIDE Final Report (Grumman Aerospace G3/18

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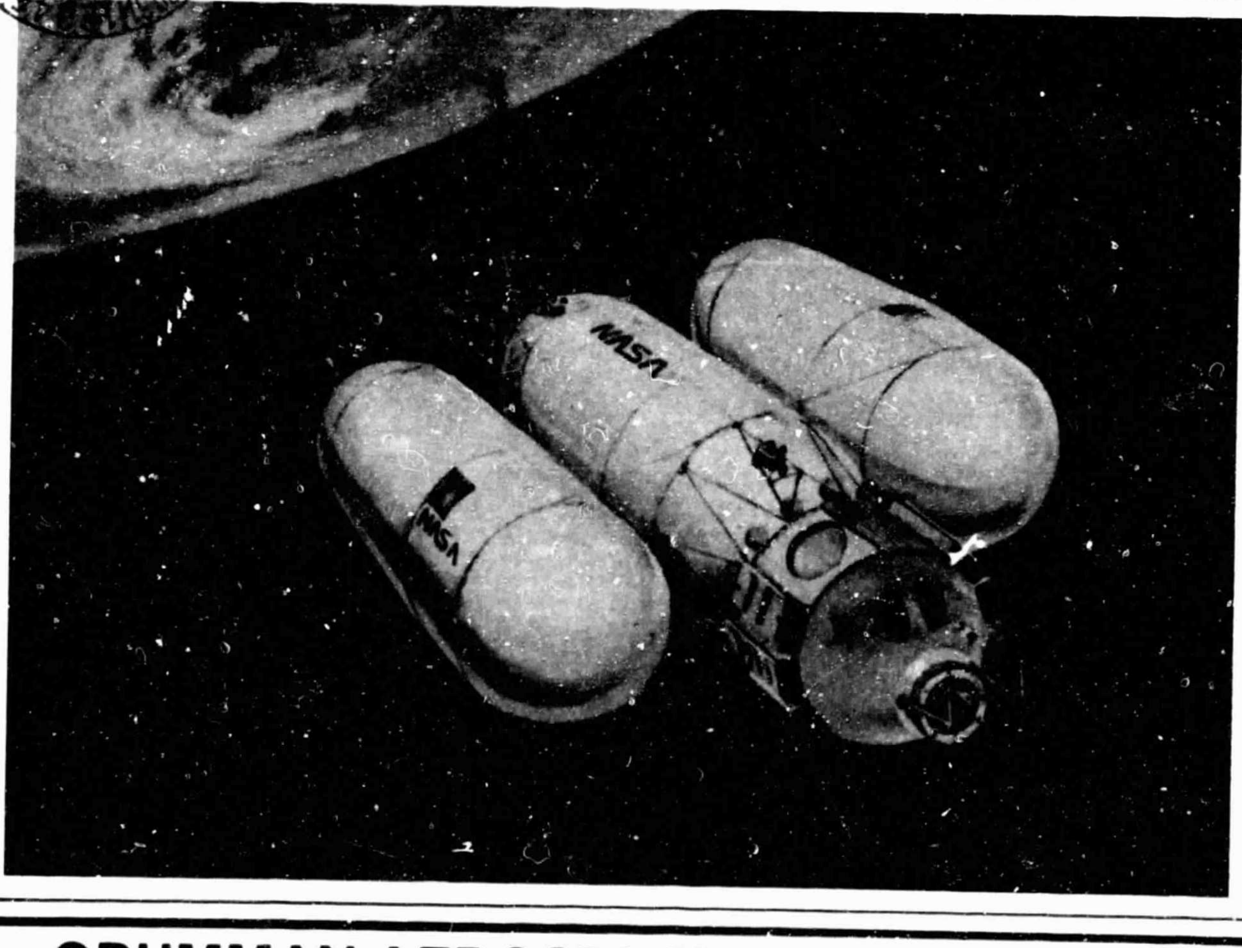
MANNED ORBITAL TRANSFER VEHICLE (MOTV) CAPABILITIES HANDBOOK AND USER GUIDE



GRUMMAN AEROSPACE CORPORATION

MANNED GEOSYNCHRONOUS MISSION REQUIREMENTS & SYSTEMS ANALYSIS STUDY EXTENSION

MOTV capabilities handbook and user guide

prepared for
National Aeronautics and Space Administration
Johnson Space Center
Houston, Texas

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February 1981

CONTENTS

Section		Page
1	CREW CAPSULE BASELINE CONFIGURATION DEFINITION	1-1
	1.1 Design Requirements	1-1
	1.1.1 Crew Capsule	1-2
	1.1.2 Crew Support	1-5
	1.1.3 Subsystem	1-5
	1.1.4 Mission Requirements	1-9
	1.1.5 Interfaces	1-9
	1.2 Crew Capsule Layout	1-10
	1.2.1 Crew Capsule External Arrangement	1-10
	1.2.2 Crew Capsule Internal Arrangement	1-12
	1.3 Mass Properties	1-14
	1.3.1 Crew Capsule Related Weights	1-14
	1.3.2 Balance & Moments of Inertia About CG	1-14
	1.4 Flight Stations	1-17
	1.4.1 Window Viewing	1-17
	1.4.2 Flight Control Station	1-17
	1.4.3 Manipulator Control Station	1-17
	1.5 Mission Task Performance	1-20
	1.5.1 IVA	1-20
	1.5.2 EVA	1-25
	1.6 Radiation Protection	1-30
	1.7 Subsystems	1-31
	1.7.1 Avionics	1-33
	1.7.2 Electric Power	1-39
	1.7.3 Environmental Control & Life Support	1-39
	1.7.4 Thermal Control	1-41
	1.7.5 Crew Accommodations	1-41
	1.7.6 Consumables	1-41

CONTENTS (contd)

Section		Page
	1.8 External Stowage Requirements	1-42
	1.8.1 Stabilizer & Manipulator	1-42
	1.8.2 Berthing & Docking	1-43
	1.8.3 Subsystems External Equipment	1-47
	1.8.4 Mission Equipment	1-47
	1.9 Interfaces	1-49
	1.9.1 Crew Capsule/Propulsion Core	1-49
	1.9.2 MOTV/Orbiter	1-51
	1.9.3 MOTV/Orbiting Satellite	1-53
	1.9.4 MOTV/EVA	1-53
	1.9.5 MOTV/Mission Control Center	1-55
2	GROWTH/EVOLUTION	2-1
	2.1 3 Man Crew Capsule	2-3
	2.2 10 Man Passenger Transport Capsule	2-7
3	POTENTIAL APPLICATIONS	3-1
	3.1 Design Reference Mission ER1	3-2
	3.2 Design Reference Mission ER2	3-9
	3.3 Design Reference Mission DR1	3-14
	3.4 Design Reference Mission S1	3-20
	3.5 Design Reference Mission C3	3-26
	3.6 Generic Missions Summary	3-33
4	TURNAROUND & SUPPORT	4-1
	4.1 Turnaround Scenario	4-1
	4.2 Ground Rules and Assumptions	4-3
	4.3 Turnaround Requirements	4-7
	4.4 Support Requirements	4-28

ILLUSTRATIONS

Fig.		Page
1.1	Generic Mission Summary	1-2
1.2.1	One-and-One-Half Stage, All Propulsive MOTV	1-11
1.2.2	Two-Man "Functional Minimum" Crew Capsule Internal Arrangement	1-13
1.3.1	Two-Man "Functional Minimum" Crew Capsule Related Weights (Kg) for Design Reference Missions	1-15
1.3.2	Two-Man "Functional Minimum" Crew Capsule Balance & Moments of Inertia About CG	1-16
1.4.1	Work Station Viewing - Typical	1-18
1.4.2	Candidate Master Control for Slave Manipulator	1-19
1.5.1	Typical Scenario - IVA Servicing of Satellite	1-21
1.5.2	Recommended Slave Arm Kinematics	1-23
1.5.3	Dextrous Manipulator Arrangement	1-24
1.5.4	Open Cherry Picker (OCP) Work Platform	1-28
1.5.5	EVA Performed Using OCP	1-29
1.7.1	MOTV "Crew Capsule Related" Subsystem Locations	1-32
1.7.2	Crew Capsule Penalties for Providing Additional Subsystems Stowage	1-32
1.7.3	MOTV Overall Command & Control System Schematic	1-34
1.7.4	MOTV Display and Control Subsystem	1-36
1.7.5	MOTV Data Management Subsystem - Added Equipment	1-37
1.7.6	MOTV Navigation and Guidance Subsystem - Added Equipment	1-38
1.7.7	MOTV ECLS Baseline Schematic	1-40
1.8.1	Berthing/Docking Options	1-44
1.8.2	Berthing Ring Configuration Interface Mechanism (BRIM) McDonnell Douglas Configuration	1-45
1.8.3	Docking Interface - Rockwell Configuration	1-46
1.8.4	Mission Equipment External Stowage	1-48
1.9.1	Propulsion Core Support of Crew Capsule	1-50

ILLUSTRATIONS (contd)

Fig.		Page
1.9.2	Crew Capsule Stowage in Orbiter Cargo Bay - Baseline Concepts	1-50
1.9.3	Crew Capsule Stowage in Orbiter Cargo Bay - Alternate Concepts	1-52
1.9.4	MOTV Mission Equipments - STS Launch Requirements	1-54
2.1	Crew Capsule Growth/Evolution Modularity	2-2
2.1.1	Three-Man Crew Capsule Main Study Results	2-4
2.1.2	Three-Man Crew Capsule Weight - Mission S1	2-5
2.1.3	Three-Man Crew Capsule Sensitivity - Structure Weight & Free Vol/Man vs Mission Duration	2-6
2.2	Two-Man Crew Capsule Sensitivity Structure Weight & Free Vol/Man vs Mission Duration	2-7
2.2.1	10-Man Passenger Transport Crew Capsule - Mission P_2	2-8
2.2.2	10-Man Passenger Transport Crew Capsule Weight	2-9
3.1.1	ER1 - Emergency Repair (GEO)	3-3
3.1.2	ER1 - Functions, Time and Tasks	3-4
3.1.3	ER1 - Timeline and Crew Requirements	3-5
3.1.4	Two-Man "Functional Minimum" Crew Capsule - Typical for all DRMs.	3-5
3.1.5	MOTV Configuration for Mission ER1	3-6
3.1.6	ER1 Summary Weight Statement kg	3-7
3.1.7	ER1 Weight Statement (Crew Capsule)	3-7
3.1.8	Performance Data - Emergency Repair Mission (ER1)	3-8
3.1.9	Typical Cost per Mission - Mission ER1 (Constant '79 $M)	3-8
3.2.1	ER2 - Emergency Repair (HEO)	3-9
3.2.2	ER2 - Functions, Time and Task	3-10
3.2.3	ER2 - Timeline and Crew Requirements	3-11
3.2.4	ER2 Summary Weight Statement, kg	3-12
3.2.5	ER2 Weight Statement (Crew Capsule)	3-12
3.2.6	Performance Data - Emergency Repair Mission (ER2)	3-13
3.2.7	Typical Cost for Mission - Mission ER2 (Constant '79 $M)	3-13
3.3.1	Mission DR1 - Debris Removal From GEO	3-15
3.3.2	DR1 - Debris Removal From GEO	3-15

ILLUSTRATIONS (contd)

Fig.		Page
3.3.3	DR1 - Functions, Time, and Tasks	3-16
3.3.4	DR1 - Timeline and Crew Requirements	3-17
3.3.5	Scenario for Mission DR1	3-18
3.3.6	DR1 Summary Weight Statement, kg	3-18
3.3.7	DR1 Weight Statement (Crew Capsule)	3-18
3.3.8	Performance Data - Debris Removal Mission (DR1)	3-19
3.3.9	Typical Cost per Mission - Mission DR1 (Constant '79 $M)	3-19
3.4.1	S1 - Modular Level Servicing (4 GEO Satellites - 90° Apart) . . .	3-21
3.4.2	S1 - Functions, Time, and Tasks	3-22
3.4.3	S1 - Typical Overall Timeline.	3-23
3.4.4	S1 - Timeline and Crew Requirements	3-23
3.4.5	S1 - Summary Weight Statement, kg	3-24
3.4.6	S1 - Weight Statement (Crew Capsule)	3-24
3.4.7	Performance Data - Service Mission (S1)	3-25
3.4.8	Typical Cost per Mission - Service Mission (Constant '79 $M) . . .	3-25
3.5.1	C3 - Assemble Communication Platform with Prefab Structure . . .	3-27
3.5.2	C3 - Functions, Time and Tasks	3-28
3.5.3	C3 - Timeline and Crew Requirements	3-30
3.5.4	C3 - Construction Summary Weight Statement	3-31
3.5.5	C3 - Weight Statement (Crew Capsule)	3-31
3.5.6	C3 - Performance Data - Construction Mission	3-32
3.5.7	C3 - Typical Cost per Mission - (Constant '79 $M)	3-32
3.6	Generic Mission Summary	3-34
3.7	Generic Missions Equipment Requirements	3-35
3.8	Generic Mission Weights - kg	3-39
4.1	OTV/MOTV Five-Year Projected Traffic and Turnaround Maintenance Cycles	4-2
4.2	Generic Mission Summary	4-4
4.3	OTM/MOTV Subsystems Allocation	4-8
4.4	OTM/MOTV Ground Turnaround Activity	4-9
4.5	Ground Turnaround Handling and Transportation Requirements . .	4-18

ILLUSTRATIONS (contd)

Fig.		Page
4.6	SOC Turnaround Activity	4-19
4.7	MOTV Service Scenario at SOC - EVA Servicing (No Hangar)	4-20
4.8	MOTV Service Scenario at SOC - EVA Servicing (No Hangar)	4-21
4.9	MOTV Service Scenario at SOC - EVA Servicing (No Hangar)	4-22
4.10	MOTV Service Scenario at SOC - Shirtsleeve Servicing (In Hangar)	4-23
4.11	MOTV Service Scenario at SOC - Shirtsleeve Servicing (In Hangar)	4-24
4.12	MOTV Service Scenario at SOC - Shirtsleeve Servicing (In Hangar)	4-25
4.13	OTV/MOTV Ground Maintenance C/O and Integration Facility	4-37
4.14	SOC MOTV Turnaround Facility	4-37
4.15	MOTV Service Facility at SOC - EVA Servicing	4-38
4.16	MOTV Service Facility at SOC - Shirtsleeve Servicing	4-40
4.17	Transportation, Mechanical, Fluids Transportation Support Equipment Requirements - Gnd & SOC Turnaround	4-41
4.18	Avionics Support Equipment Requirements - Gnd & SOC Turnaround	4-42

TABLES

Table		Page
4.1	Crew Module Display and Controls	4-10
4.2	Data Management Subsystem	4-10
4.3	Attitude Control and Guidance	4-11
4.4	Tracking, Telemetry, and Command	4-11
4.5	Rendezvous Radar	4-12
4.6	Electrical Power Subsystem (EPS)	4-13
4.7	ECLS Subsystem	4-14
4.8	RL 10 II B Main Engine	4-15
4.9	Propulsion System	4-16
4.10	Attitude Control Propulsion System	4-16
4.11	OTV/MOTV Integrated Functional Requirements - Ground Overhaul Operations	4-29
4.12	SOC Turnaround Support Requirements for MOTV Crew and Prop Core	4-33
4.13	Ground Overhaul Maintenance Manpower Required	4-43
4.14	SOC Post Flight and Periodic Maintenance Manpower Required	4-43

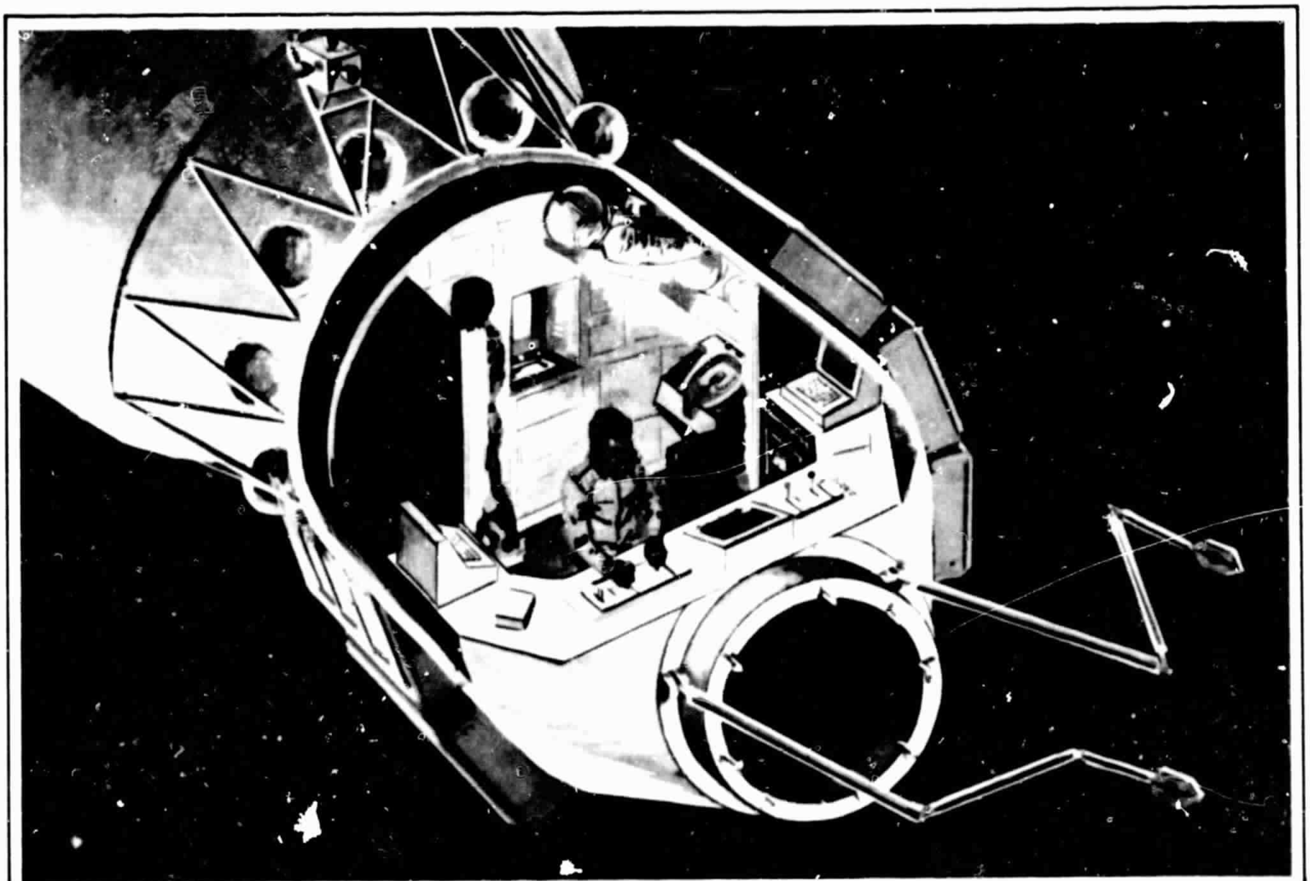
INTRODUCTION

This handbook is intended to provide the user with a comprehensive definition of a baseline MOTV crew capsule, and its capabilities in performing manned missions to geosynchronous or other high energy orbits. This document supplements and updates previously published reports issued as part of the MGMRSAS Phase 2 MOTV Final Report, e.g., Mission Handbook, Program Requirements Document and Turnaround Analysis.

The primary change in crew capsule definition from the Phase 2 final report is a smaller MOTV crew capsule, switching from a 3-man capsule to a 2-man capsule. A second change permitted crew accommodations for sleeping and privacy to be combined with the flight station.

The previous 3-man crew capsule was designed around a design reference mission (DRM), S1, which serviced four MMS-type satellites in GEO and required 19 days to complete with a rather large amount of mission-dedicated hardware. The current baseline DRM, ER1, is much less ambitious, requiring 2 men for 3 to 4 days to repair a multi-disciplined GEO Platform and a modest amount of mission-dedicated hardware.

The sections that follow describe in detail a 2-man MOTV crew capsule to be used as a design reference point for the OTV, and its interfaces between the STS and other associated equipment or facilities. The functional capabilities of the 2-man capsule, as well as its application to a wide range of generic missions, is also presented. The last section of this report addresses MOTV turnaround and identifies significant requirements for both space-based and ground-based scenarios.



1 - CREW CAPSULE BASELINE CONFIGURATION DEFINITION

To establish MOTV mission requirements at the beginning of this study, a broad range of generic missions was identified, as shown in Fig. 1.1. This was an unmanageable number for detailed study and so five of them (S1:ER1:ER2:DR1:C3) were selected as Design Reference Missions (DRMs). During the study extension, it was determined that a crew of two could perform these five DRMs. Therefore, a two man crew capsule is baselined.

Earlier considerations in the study gave separate, private quarters to each man. However, each kilogram transported round trip to GEO costs in the order of $10,000. It was decided, therefore, that in the study extension, weight should be minimized by combining crew relaxation/sleeping functions with the work stations, thus eliminating the separate quarters. Furthermore, just adequate facilities would be provided for other crew comforts and for subsystems stowage. The resultant configuration is a functionally adequate layout with minimum frills.

1.1 DESIGN REQUIREMENTS

This subsection defines the main requirements for a manned capsule to house a crew of 2 and to perform the design reference missions. The requirements are extracted mainly from the Program Requirements Document issued at the end of the Manned Geosynchronous Mission Requirements and Systems Analysis Study (MGMRSAS), NASA Contract NAS9-15770. That document, which identifies rationale and source, is more comprehensive and should be consulted if more detail is required. The MGMRSAS study extension has modified or augmented some of the earlier requirements and these are included here:

The requirements fall into five categories:

- Crew capsule general requirements
- Crew support requirements
- Subsystems requirements
- Mission Equipments
- Interfaces

GENERIC MISSION		SCENARIO CHARACTERISTICS				
CATEGORY	SYMBOL	ORBIT	MISSION HDWR, Kg	CREW*	DURATION, DAYS	DESCRIPTION
INSPECTION SERVICE & REPAIR	IN1	GEO	510	2	4	SCIENTIFIC SATELLITE REVISIT
	$\boxed{S1}$	GEO	1000	2	10	MODULAR LEVEL SERVICE
	S2	GEO	2000	2	27	COMPONENT LEVEL SERVICE & UPDATE
	S3(a)	GEO	2040	2	21	SERV & UPDATE NUCL PWRD SATS
	S3(b)	GEO	2000	2	3	REPLACE NUC REACTOR
	$\boxed{ER1}$	GEO	463	2	4	EMERGENCY REPAIR (GEO)
	$\boxed{ER2}$	12 HR/63	272	2	4	EMERGENCY REPAIR (MEO)
	R1	12 HR/63	4100	2	2	FAILED SATELLITE
OPERATION OF LARGE SPACE SYSTEM	OP1	GEO	440	2	16	TENDED STD
	P1	GEO	1003	2	4	3 MAN CREW ROTATION/RESUPPLY
	P2	GEO	4406	2	4	10 MAN CREW ROTATION/RESUPPLY
	P3	GEO	16,019	2	4	30 MAN CREW ROTATION/RESUPPLY
	P4	DEEP SPACE	3304	2	30	6 MAN CREW ROTATION/RESUPPLY
DEBRIS REMOVAL	$\boxed{DR1}$	GEO	550	2	9	REMOVE DEBRIS FROM 45 SECTOR OF GEO
CONSTRUCTION	C1	GEO	10,000	2	3	UNFOLD WIRE WHEEL ANTENNA
	C2	GEO	16,000	2	6	UNFOLD COMMUN PLATFORM
	$\boxed{C3}$	GEO	17,000	2	6	PREFAB COMMUN PLATFORM
	C4	GEO	15,000	2	7	AUTOFAB COMMUN PLATFORM
	C5	GEO	110,535	3	14/5/5/5	AUTOFAB SPDA
	C6	GEO	-	2	17	MODULAR ASSY SPDA
UNMANNED CARGO	UC	VARIOUS	15,000 55,000	NONE		SECONDARY ROLE

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SYMBOLS

IN - INSPECTION
S - SERVICE
ER - EMERG REPAIR
R - RETRIEVAL
OP - OPER. LG SPACE SYSTEM
P - PASS. TRANSPORT
DR - DEBRIS REMOVAL
C - CONST
UC - UNMAN. CARGO

DESIGN REFERENCE MISSIONS (boxed)

*MIN. TO PERFORM TASKS IVA

Fig. 1.1 Generic Mission Summary

1.1.1 Crew Capsule

1.1.1.1 Design life shall be 30 missions, based on 3 missions per year for 10 years.

1.1.1.2 A two-gas (oxygen and nitrogen) atmosphere shall be provided with internal pressure at 5.52N/m^2(8.0psi).

1.1.1.3 There shall be two ingress/egress latches, each 1m diameter, in the pressure shell.

1.1.1.4 Windows shall be provided to permit viewing of docking aids, grappling operations and manipulator assembly tasks. Size shall be minimized.

1.1.1.5 Mounts shall be provided for mission equipments, outboard of the pressure shell, in areas not required for subsystems, ingress/egress and for viewing from capsule windows.

1.1.1.6 Externally mounted subsystems or equipments shall not inhibit ingress/egress from the capsule, mission abort, or transportation in the orbiter cargo bay.

1.1.1.7 Cabin design shall accommodate EVA operations.

1.1.1.8 Crew transfer between Orbiter or other habitable modules and the crew capsule shall be in a shirt sleeve pressurized environment.

1.1.1.9 Docking and berthing shall provide equipment to interface with the Orbiter docking module and withstand loads of TBD.

1.1.1.10 Safety

- Distribution of overall failure probability among critical subsystems shall be as given below. The percentage column shows the proportion of catastrophic failure "allowed" for each subsystem. The final column shows the same distribution in terms of the mean number of missions between fatal failures scaled to match an overall safety level of one fatal MOTV failure in 1000 missions.
- No single malfunction or reasonable combination of malfunctions shall result in the potential of injury to MOTV, Orbiter and ground personnel.

CRITICAL SUBSYSTEM	% ALLOCATION	MISSIONS PER CATAST FAILURE
EPS	8	12,000
AVIONICS	7	14,000
ECLS	10	10,000
RADIATION PROTECTION	12	8,000
CREW TRANSFER	3	30,000
FOOD/WATER	0	
OVERALL STRUCTURE	0	
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MOTV Man Rating – Preliminary Allocation of Catastrophic Failure Likelihood

1.1.1.11 Radiation Protection

- Allowable crew dosage shall be based on STS limits. If greater or lesser levels of risk are acceptable, these limits shall be adjusted accordingly.

- **The system shall provide the following for GEO & 12 Hour Orbit:**
  - **Warning of any event predicted to reach or exceed 10^8 p/cm^2 total event flux of protons $\geq$ 30 MEV.**
  - **Deorbit capability to return to an altitude less than 3 earth radii within 6 hours**
  - **Crew shielding sufficient to survive a solar event of 10^9 p/cm^2 total event flux or protons $\geq$ 30 MEV.**
- **Since timely deorbit is impractical for deep space orbits the system shall provide crew shielding sufficient to survive a solar flare event of 10^{10} p/cm2 total event flux of protons $\geq$ 30 MEV.**
- **Personal active/passive dosimetry and other onboard radiation instrumentation shall be such that depth-dose information is provided in realtime. Also it shall be able to identify the portion of the total dose attributable to radiation components with differing LET. The need to monitor exposure to high energy Z particles will be required.**
- **The combined exposures for the total mission shall include accumulated doses during orbital transfer, possible EVA, IVA operations, and other possible unscheduled radiation environment.**
- **To minimize radiation hazards the following telemetry/caution and warning displays shall be provided:**
  - **Early warning (minimum 2 days) advanced warning of an anomalously large solar flare event.**
  - **Continuous monitoring of dose rate limits.**
  - **Spacecraft charging monitoring.**
- **Deterministic capability (i.e., 100% probability) of long term solar flare prediction of at least TBD days "before" flare occurrence, shall be developed.**

1.1.1.12 Reliability

- **Subsystem or component failures shall not propagate sequentially. Equipment shall be designed, as a minimum, to be fail-operational/failsafe.**

- All critical life limited components and subsystems shall be designed to facilitate inspection. Redundant paths shall be located so that an event which damages one path is not likely to damage the other.
- The capsule shall provide the capability for performing critical functions at a nominal level with any single component failed and at a reduced level with any credible combination of two component failures.

1.1.1.13 Maintainability

- The capsule shall be designed to provide access to equipment interfaces, equipment installations, and service umbilicals requiring inspection, servicing or verification during scheduled ground maintenance and prelaunch operations.

1.1.2 Crew Support

1.1.2.1 Habitability shall cater to mixed gender crews by providing privacy for bodily functions and for relaxation. It shall also provide an active waste management system, a personal hygiene station to support hand and body washing, a gallery with heating for food and water.

1.1.2.2 Health diagnostics/monitoring shall be provided for all crew critical functions with adequate data warning for the crew and ground personnel.

1.1.2.3 In case of serious illness or accident, the MOTV shall have the capability to return to the Orbiter within 24 hours and to the ground within an additional 24 hours.

1.1.3 Subsystem

1.1.3.1 Warning of subsystem malfunctions shall be given to the "on" and "off duty" MOTV crew, the ground support personnel and the orbiter crew (when in the mated configuration).

1.1.3.2 When the functional system failure results in the significant depletion of a critical consumable (power, life support, etc.) reserve shall be provided for TBD hours.

1.1.3.3 All subsystem equipment which does not require manned interface in the pressurized cabin shall be mounted externally.

1.1.3.4 Subsystems shall adequately support the mission plus a contingency reserve of 4 days for 2 crew.

.1.3.5 **Structure**

- **Cabin pressure structure shall be designed for 5.52 N/M^2 (8.0 psi) nominal pressure with an ultimate strength factor of 2.0X maximum relief valve pressure.**
- **Windows shall have an ultimate strength of 3.0X maximum relief valve pressure.**
- **The capsule shall be designed to withstand berthing and docking loads of TBD.**
- **The structure shall be designed to withstand Orbiter launch and landing loads specified in JSC-07700, Vol. XIV.**

.1.3.6 **Avionics**

- **Displays and controls shall:**
  - **Provide sufficient duplication to permit the vehicle to be piloted from either the pilot or mission operations stations.**
  - **Display caution and warning data obtained from Data Management for malfunction identification.**
  - **Display Closed Circuit TV (CCTV) during IVA and provide controls to operate the manipulators.**
  - **Supply dedicated switches, controls and instruments to monitor, command and control all vehicle subsystems during operation of the MOTV.**
  - **Display the range and bearing information from the passive and cooperative targets during rendezvous operations.**
- **Data management shall·**
  - **Accept status inputs from the various electronic subsystems, main engine, ACPS, fuel distribution system and the drop tanks.**
  - **Utilize conditioned status inputs so that the Caution and Warning Electronics can drive the crew displays of caution and warning data on the vehicle.**
  - **Accept Bio-Med Inputs from the crew for transmission to the ground regarding the health status of the crew members.**

- Accept ECS and Life Support inputs for display in the capsule and transmission to the ground.

- Attitude control shall:
  - Provide attitude and velocity change information from the inertial measuring unit.
  - Provide automatic and manual control capability for all mission phases except docking, which is manual only.
  - Provide attitude and steering displays for the crew.
- Tracking, Telemetry and Communications shall:
  - Provide voice communication between crew stations and between the MOTV and the ground stations and Shuttle.
  - Provide voice synthesis and recognition for EVA command and control of the vehicle.
  - Generate, transmit and distribute closed-circuit television (CCTV) in the capsule.
  - Transmit MOTV status and crew health to the ground via RF Link.

1.1.3.7 Electrical Power

- All prime power generation, storage, control and conditioning functions shall be located on the propulsion module and be capable of autonomous operation. Capsule electrical power requirements shall be provided via a remote load control and distribution center, located within the capsule.
- The maximum power to be made available to MOTV user loads shall be 5.0 kW.
- The maximum energy requirement will be 3000 kW-hr for missions up to 30 days in duration.
- A minimum of 50 kW-hr of emergency energy shall be continuously held in reserve during a mission.
- The MOTV shall be capable of receiving up to 2.0 kW of Orbiter power. The interface shall include provisions for monitoring and control of critical MOTV EPS functions.

1.1.3.8 Environmental Control and Life Support shall:

- Provide a shirtsleeve environment with the following conditions:
  - Temperature: Normal 18°C - 24°C 62°-75°F
    Emergency 10°C - 32°C 50°-90°F
  - Humidity Dew Point 10°C - 16°C 50°-60°F
  - Pressure (O_2/N_2) 0.5 bar - 0.6 bar 7.5 - 8.5 psia
  - CO_2 partial pressure 3-5 mmHg.
  - Cabin Leakage 1 Kg/Day 2.2 lb/Day
- Provide for the following metabolic values:
  - Avg Metabolic Rate 11,200 Btu/Man Day
  - CO_2 Produced 0.96 kg/Man Day
  - Condensate 1.58 kg/Man Day
  - O_2 Required 0.83 kg/Man Day
  - Potable Water Req'd 2.35 kg/Man Day
  - Urine Produced 2.06 kg/Man Day
- Be designed to be fail safe with at least 96 hours survival provisions.
- Have emergency pressurization to maintain the cabin at 8 ±0.5 psia for 1/2 hour with leakage equivalent to 1/4 inch diameter hole.

1.1.3.9 Thermal Control shall:

- Provide thermal heat rejection system to maintain/remove capsule heat and electrical/electronic equipment heat.

  Provisional loads to be used are:
  - ECLS 655W (2235.5 Btu/hr)
  - Metabolic/Man 137W (467 Btu/hr)
  - Avionics 800W (2760 Btu/hr)
- Not require selected capsule orientation in orbit to maintain its thermal control function.

1.1.3.10 Crew Accommodations shall:

- Provide free volume per man to give Celetano 'tolerance' comfort level for a 27 days mission ($3.0m^3$).
- Accommodate male and female operators in the 5th to 95th percentile anthropometric range.
- Keep continuous noise levels to below 50 dB in the 600 to 4800 Hz range and 70 dB above 4800 Hz.

1.1.3.11 Guidance, Navigation and Control shall:

- Permit manned docking/berthing of the MOTV to the Orbiter and to other spacecraft.
- Provide control authority for:
  - Rotational Acceleration of $10°/sec^2$
  - Translation of $0.3\ ft/sec^2$
- Limit Attitude deadband to ±0.1°

1.1.4 Mission Requirements

Major support equipment for the baseline mission shall be:

- Remotely operated manipulators -
  2 required: 2.5m reach: 7 DOF
- Berthing stabilizer
  1 required: 2.0M reach: 4 DOF
- Berthing ring
- EVA Suits
  2 required: GEO type: 2 contingency +1 emergency EVA of 6 hours each.
- Equipment stowage racks
- Check out and calibration equipment
  These equipments are of general use for 80% of the generic missions.

1.1.5 Interfaces

1.1.5.1 Shuttle

The crew capsule shall:

- Not degrade STS integrity/safety

- Fit within the Orbiter payload bay and be compatible with STS structural, dynamic, mechanical, electrical, fluid and operational requirements.
- Provide a berthing/docking system compatible with the Orbiter.

The Orbiter shall provide at least the following non-standard support, changeable to the payload:

- Orbiter crew accommodations, in addition to the Standard 28 man days, of TBD.
- Transfer tunnel connecting crew capsule to Orbiter cabin for shirt sleeve transfer of MOTV crew.
- Electrical power of TBD kwh in support of activities while the MOTV is attached to the Orbiter.

1.1.5.2 Launch Facilities

The crew capsule shall be compatible with launch site facilities used for turnaround operations.

1.1.5.3 Communications

Uplink and downlink shall be compatible with the Orbiter, MSFN, STDN, TDRSS and SOC.

1.2 CREW CAPSULE LAYOUT

The MOTV configuration presented in Fig. 1.2.1 shows a 1-1/2 stage, all propulsive, orbital transfer vehicle leaving LEO on a manned mission. A crew capsule mounts to the front of a propulsion core which is surrounded by jettisonable tanks containing propellant.

1.2.1 Crew Capsule External Arrangement

The crew capsule outboard profile shows a truss structure mounting the capsule to the propulsion core. Within this structure, those subsystems components which do not require on orbit access or which are a safety hazard, can be stowed. Thermal control radiator panels are mounted, and mission equipments may be mounted, external to the capsule along its cylindrical section. These mountings must not inhibit ingress/egress through the EVA hatch located in the capsule shell.

Looking at the forward end of the capsule, a berthing or a docking ring, dependent upon the mission, is mounted to the capsule boarding hatch for mating

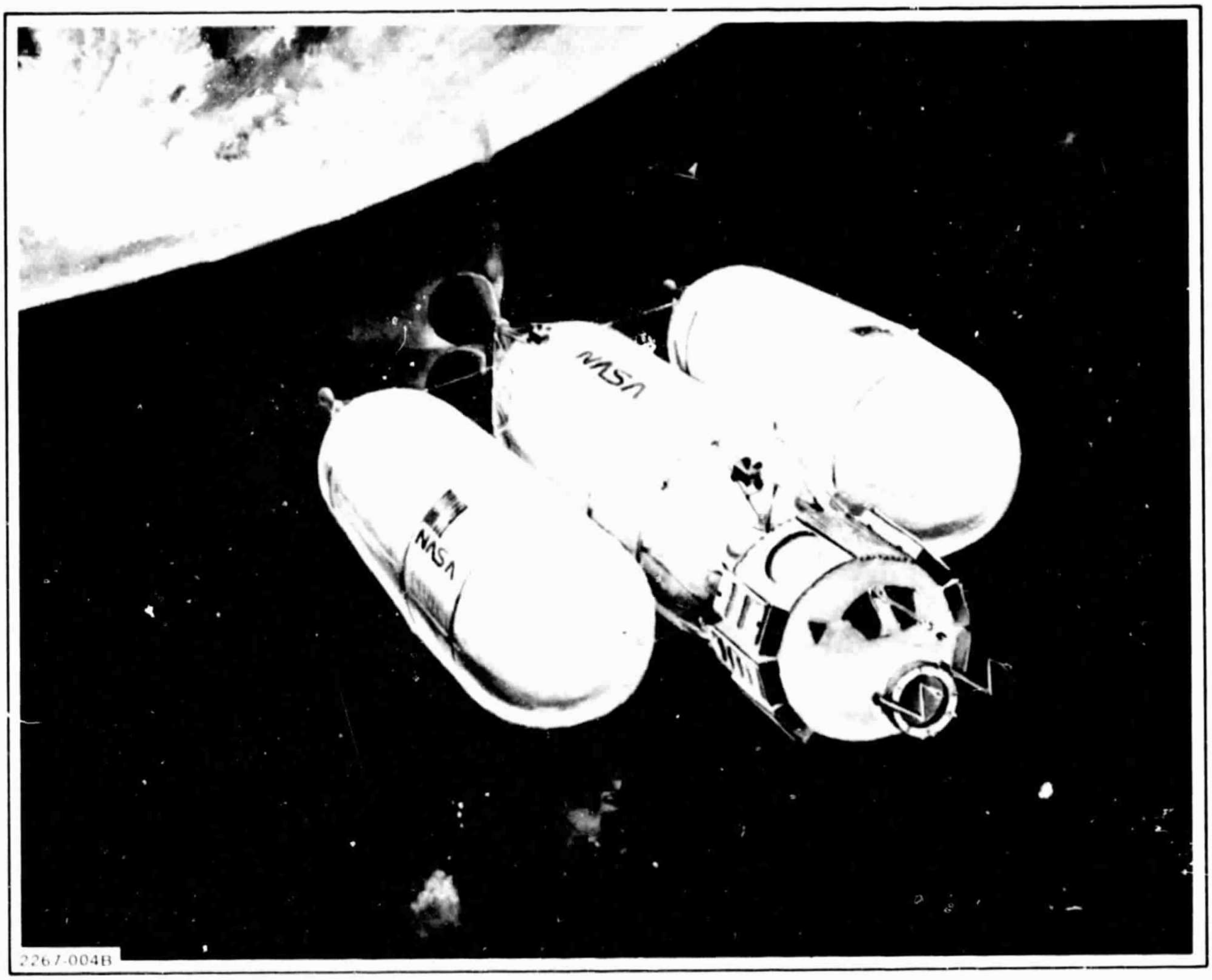

Fig. 1.2.1 One-and-One-Half Stage, All Propulsive, MOTV

the MTOV to the shuttle or to an orbiting pressurized body requiring manned shirt sleeve transfer. For mating to an orbiting satellite which does not require manned shirt sleeve transfer, a grappling stabilizer is mounted to the capsule between the viewing windows. It has four degrees of freedom and has an end effector which grabs a fitting on the satellite and joins the two bodies. On those missions requiring work external to the crew capsule, such as servicing and construction, it may be performed by operators working from within the capsule using two master/slave manipulator systems. The slave manipulators are mounted, as shown, to the structure supporting berthing and docking. They have seven degrees of freedom.

Other sections of this report quantify the facilities discussed here.

1.2.2 Crew Capsule Internal Arrangement

Figure 1.2.2 shows the internal configuration of a 2 man 'functional minimum' crew capsule whose objective is to provide functionally adequate, but no more, living facilities, subsystems storage and free volume necessary for crew movement and EVA suit donning. The free volume is about $3.0m^3$ per man.

At the forward end, two crew stations for flight and mission operations provide the necessary controls, displays and subsystems. Windows provide viewing of docking/berthing and work zones. Off duty, the crewman can pivot in his seat for about 180° from his work position. Privacy is obtained by drawing curtains around his territory. Aft of this compartment, a galley and a waste management system cater to crew comforts. A curtain can be drawn to give privacy when using waste management or when washing the body at the personal hygiene facility located inside the rear dome. Subsystems are located under the floor and inside the rear dome as well as surrounding the flight/mission stations.

EVA suits are stored above the waste management facility and can be donned, in turn, in a 1.12m x 1.12m area bounded by galley, waste management, aft subsystems and the work station zone. A hatch for EVA ingress/egress is located above this area.

Other sections of this report quantify facilities discussed here.

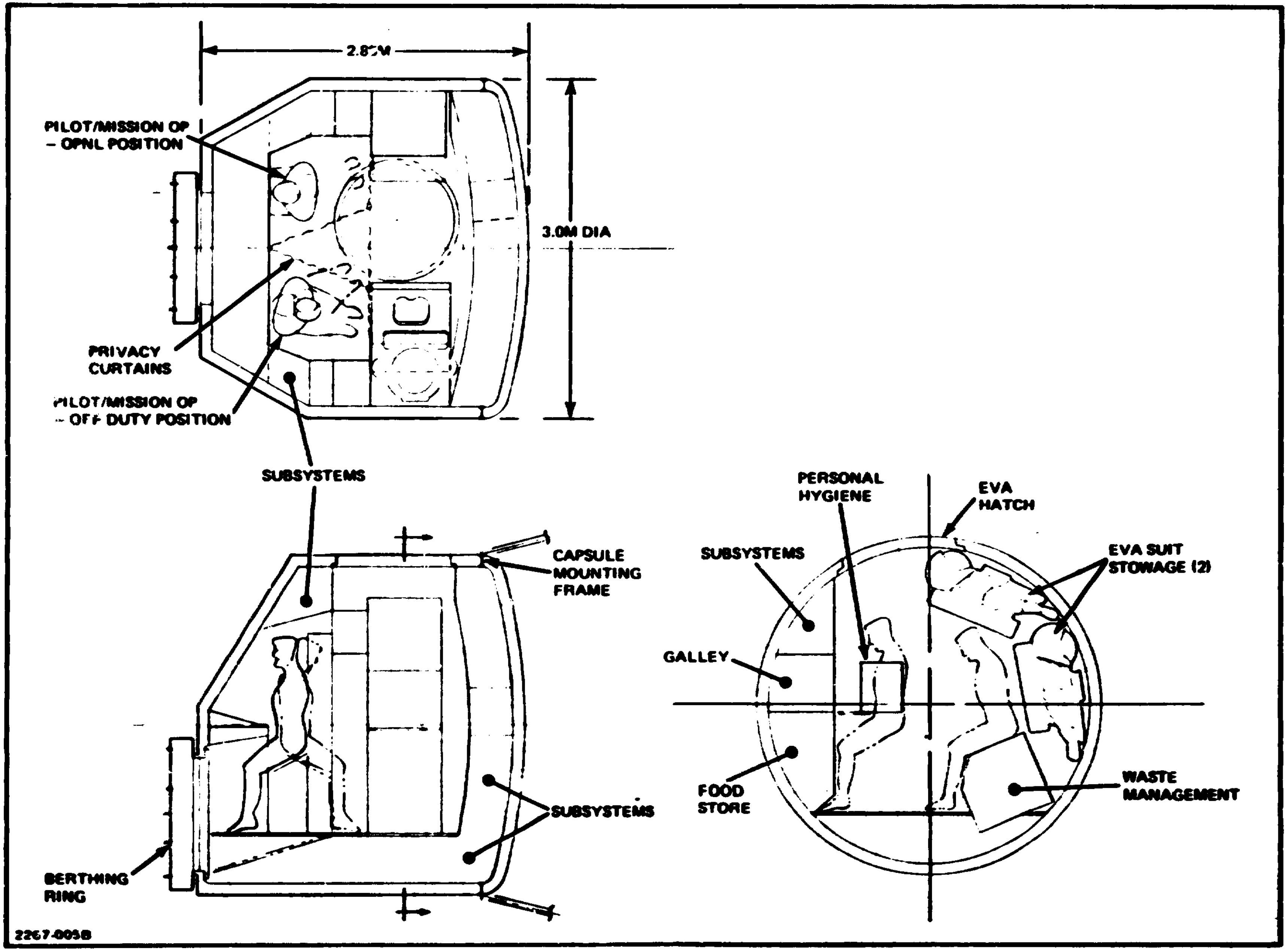

Fig. 1.2.2 Two-Man "Functional Minimum" Crew Capsule – Internal Arrangement

1.3 MASS PROPERITES

1.3.1 Crew Capsule Related Weights

For each of the five (5) Design Reference Missions (DRM) Fig. 1.3.1 gives preliminary weights for the 'functional minimum' crew capsule and its associated subsystems carried in the propulsion core. These weights, plus the general purpose and dedicated mission equipments defined elsewhere in this report, are the OTV payload for each mission. Throughout the main study and this extension, a contingency of 25% has been added to capsule weights and 15% to the propulsion module weights.

The crew capsule structure reflects radiation requirements and its shell thickness is equivalent to 1.2 cm of aluminum. Allowance is made for hatches, windows, decks, berthing ring, etc. Capsule EPS weight estimate is for power distribution and control only. The ECLS subsystem includes equipment and plumbing for CO_2 removal and humidity control, temperature control, pressure control, and avionics cooling. Tanks are included for oxygen, nitrogen, potable water and emergency oxygen. Crew accomodations include weight for two EMUs, equipment for food preparation and stowage, waste management, personal hygiene, housekeeping, and lockers. Entertainment devices are also included. Consumables include potable water, nitrogen and oxygen, emergency oxygen, food, personal hygiene, and waste management. The propulsion core houses all subsystems necessary for unmanned flights (i.e. no crew capsule). When a manned flight is scheduled and the crew capsule added to the configuration, then relevant propulsion core subsystems are augmented to satisfy the increased requirements. These delta weights are shown here for the DRMs.

1.3.2 Balance and Moments of Inertia about CG

For mounting the crew capsule to the propulsion core and for overall vehicle control, it is necessary to know not only the mass but also location of the center of gravity (cg) and the moments of inertia about that cg. We show these parameters in Figure 1.3.2 for the heaviest of the DRM's, S1. They may be taken as typical for a crew capsule with no mission equipment mounted to it. Mass and location of these equipments will vary greatly from mission to mission and their effect on cg and inertias must be examined for each mission!

	S1	ER1/2	DR1	C3
• CREW CAPSULE				
STRUCTURE	1,113	1,113	1,113	1,113
THERMAL PROTECTION	33	33	33	33
EPS DISTRIBUTION	37	37	37	37
AVIONICS: COMMAND & DISPLAY	125	125	125	125
ECLS	296	296	296	296
CREW ACCOMMODATIONS	610	610	610	610
PROPULSION CONTROL	6	6	6	6
CONTINGENCY (25%)	555	555	555	555
TOTAL DRY WEIGHT	2,775	2,775	2,775	2,775
CREW (2)	163	163	163	163
CONSUMABLES	255	114	161	133
BURNOUT WEIGHT	3,193	3,052	3,099	3,071
• PROPN CORE: CAPSULE ASSOCIATED SUBSYS				
FUEL CELLS/TANKS/LINES	404	341	341	341
SOLAR ARRAY	193	–	–	–
CONVERSION/DISTRIBUTION	120	40	40	40
AVIONICS	30	30	30	30
RADIATOR FOR FUEL CELL Δ	8	8	8	8
CONTINGENCY (15% OF ABOVE)	113	63	63	63
FUEL CELL REACTANTS	370	175	323	244
TOTAL CAPSULE & RELATED WEIGHT	4,431	3,709	3,904	3,797

NOTE: EXCLUDES MANIPULATORS, ETC: CHARGED TO GENERAL PURPOSE MISSION EQUIPMENT

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Fig. 1.3.1 Two-Man "Functional Minimum" Crew Capsule - Related Weights (kg) for Design Reference Missions

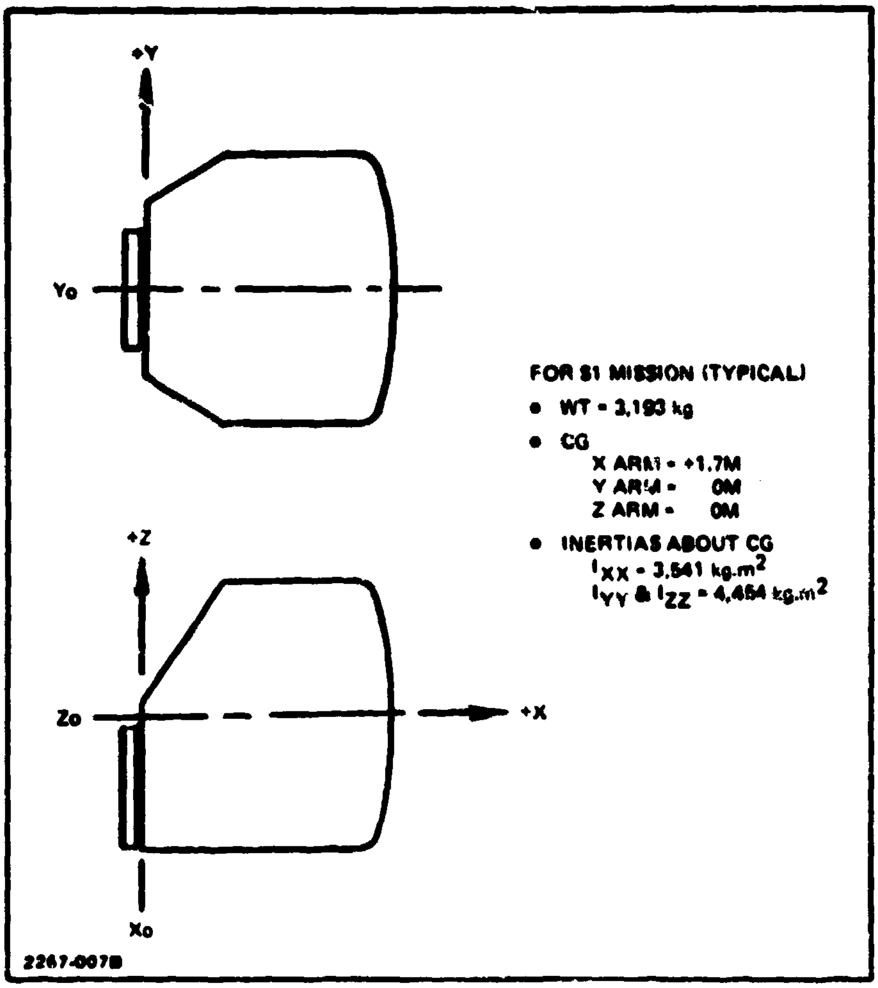


Fig. 1.3.2 Two-Man "Functional Minimum" Crew Capsule – Balance & Moments of Inertia About CG.

1.4 FLIGHT STATIONS

There are two flight stations, side by side, at the forward end of the crew capsule. These two stations can be seen in Fig. 1.2.2. As presently defined, one station controls the flight of the MOTV when docking or when using the stabilizer to berth. The same station also controls movement of the workpiece relative to the MOTV by articulating the stabilizer. The second station has, as its main function, control of the manipulator system when performing mission tasks using IVA. There will also be a back-up control at this station for docking or berthing in the event that the primary flight control station, or its operator, cannot perform its function. Necessary subsystems, controls and displays surround the two stations. Windows are located in front of each operator for viewing the workpiece or the docking/berthing target.

1.4.1 Window Viewing

For crew operated flight control, i.e., rendezvous, docking or berthing, direct viewing of the target is provided by the window. Similarly, the work area is viewed directly by the manipulator operator, through his window. To date, the study has not required comprehensive evaluation of view angles necessary to perform all the mission tasks for, say, the DRMs. Until that is done, the view angles shown in Fig. 1.4.1 should be used.

As an objective, window size will be kept to a minimum because of thermal considerations and the loss of area for mounting controls and displays.

1.4.2 Flight Control Station

One of the two flight stations controls MOTV flight for rendezvous with an orbiting body, target docking and for berthing using the stabilizer. It can control the firing of main and RCS engines. Once berthed, the stabilizer can be articulated so that actuation of its joints moves the workpiece relative to the MOTV to position the work zone as required for viewing and for manipulator access. This operation is also controlled from this station. Detailed layout of this station has not been required to date in this study but preliminary investigation into the mounting of necessary controls, displays and subsystems, so far defined, shows adequate room.

1.4.3 Manipulator Control Station

The other flight station controls the two manipulator arms used for IVA mission tasks. Being a master/slave system, the two masters are located at this work station. Figure 1.4.2 shows an operator using an 'over the shoulder' master control. This

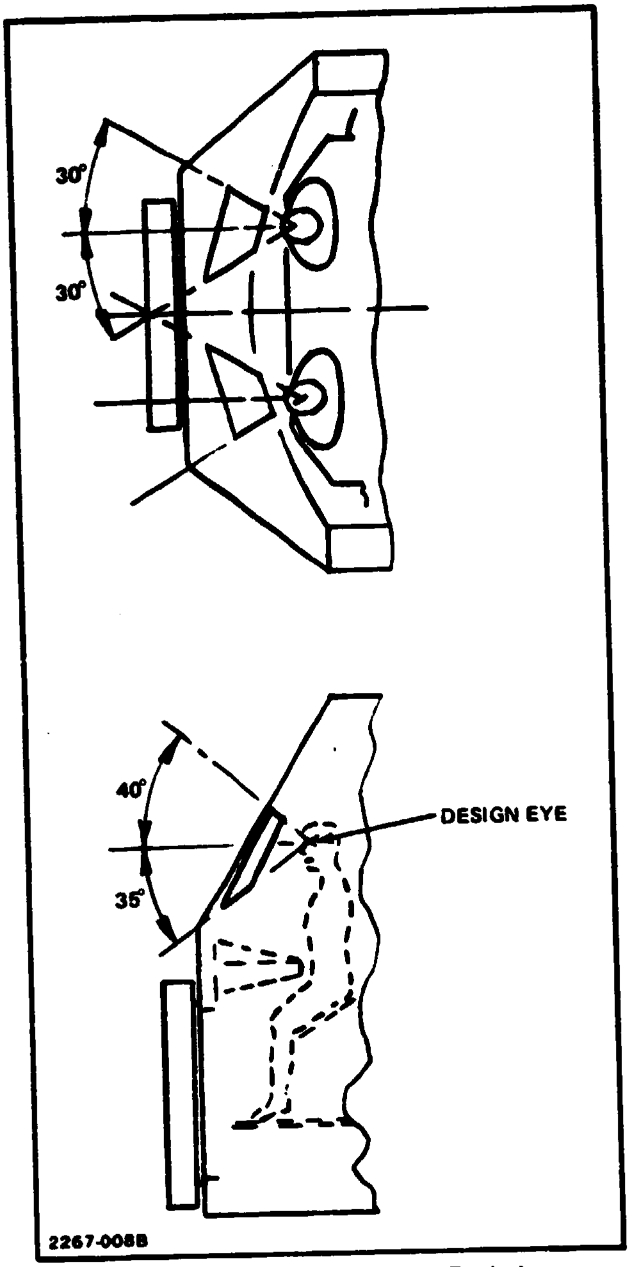


Fig. 1.4.1 Work Station Viewing-Typical

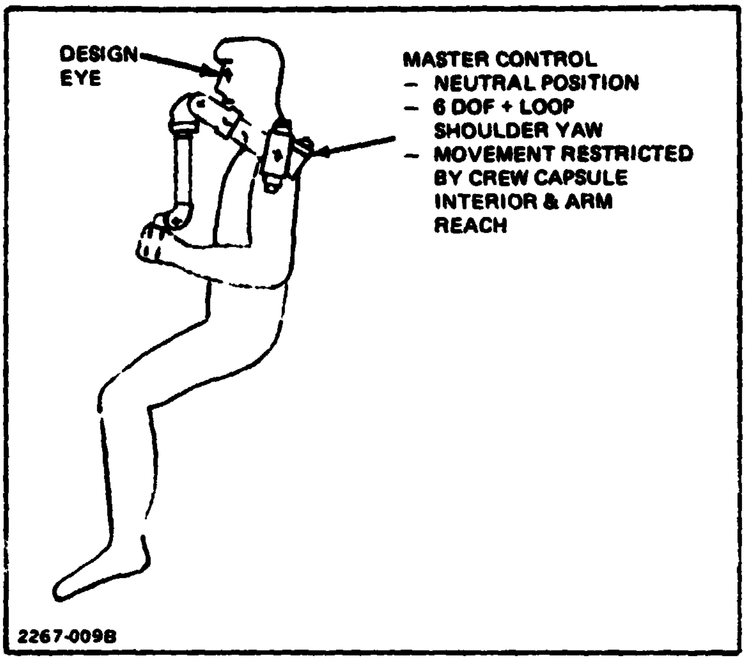


Fig. 1.4.2 Candidate Master Control for Slave Manipulator

control can be switched 180° and be operated in the attitude shown in Fig. 1.5.3. A preferred position to suit MOTV operations would be determined by demonstration, using a flight stations mock-up and the manipulator test articles being developed for the MRWS program. This station also has back-up controls for rendezvous, docking and berthing the MOTV.

Here again, layouts have not been made for this station but preliminary investigation shows adequate room to mount necessary controls, displays and subsystems.

1.5 MISSION TASK PERFORMANCE

Two options are available for performing those on orbit tasks requiring activity external to the crew capsule. They are Intra Vehicular Activity (IVA) where all work is controlled from within the crew capsule by crewmen operating remotely controlled devices, such as manipulators and T.V. cameras: Extra Vehicular Activity (EVA) where crewmen, clad in pressure suits, go outside the capsule to perform the tasks. They may have work platforms such as MRWS, to support them.

1.5.1 IVA

This is the preferred method for performing external tasks. Studies performed under this contract show that productivity is higher with IVA than with EVA, that the weight penalty is less and that it is less hazardous for the crewman. A typical scenario, illustrating mission tasks performed IVA, is shown in Fig. 1.5.1 where a satellite has MMS modules replaced. The first two steps show the change out of two MMS modules using two manipulators to perform the changeouts and a stabilizer to hold, control and move the satellite. Changing the third and last module requires either releasing the satellite and reberthing to it in a more convenient location or the satellite may be juggled by the stabilizer and the manipulators to bring the third module within view of the operator and reach of the manipulators.

If this last task could be performed by one of the manipulators, then the second manipulator could hold a TV camera for remote viewing by the operator. This would obviate the need for reberthing or juggling the satellite. This option is not shown on the sketch.

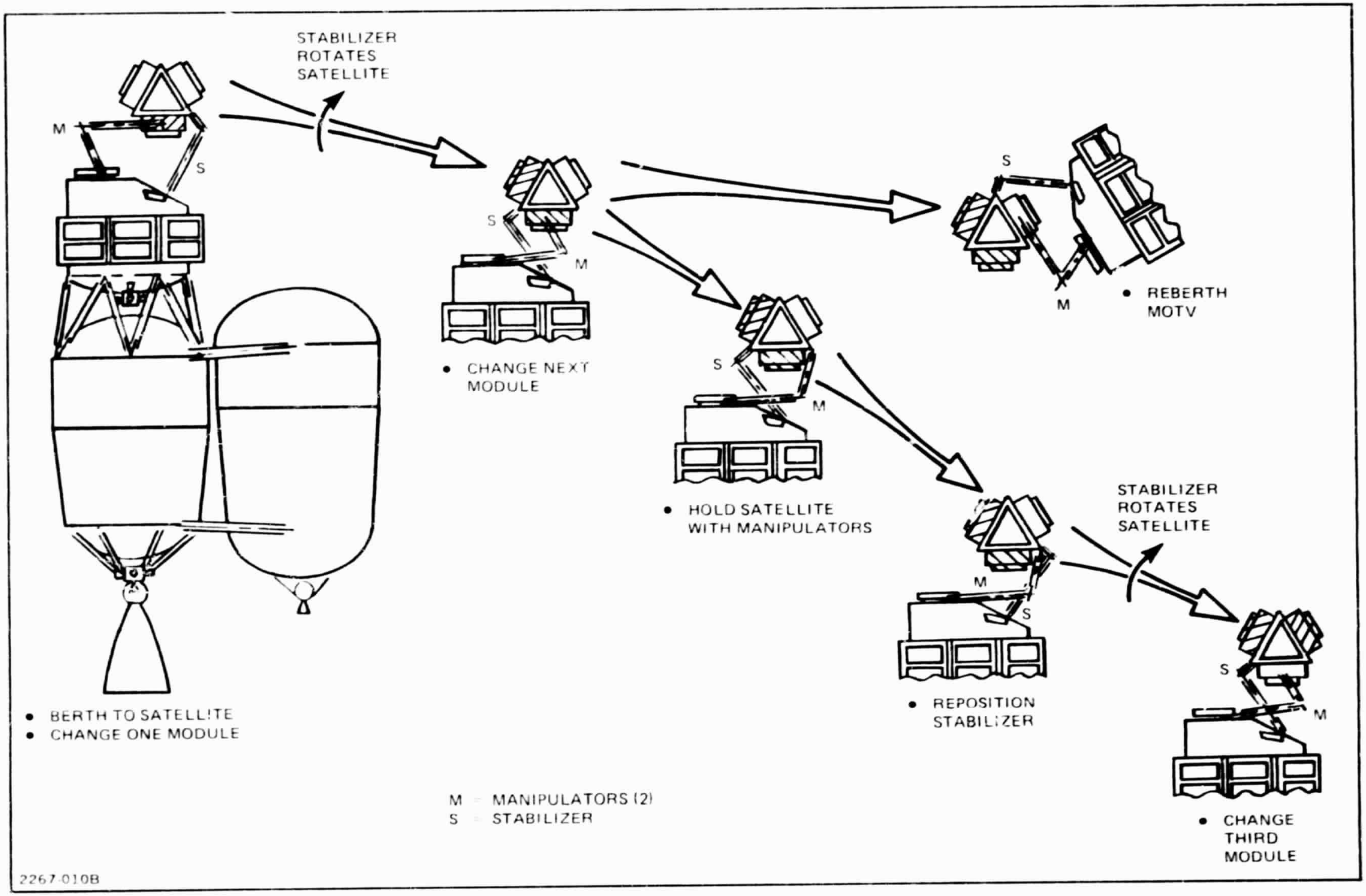


Fig. 1.5.1 Typical Scenario – IVA Servicing of Satellite

1.5.1.1 Equipments and facilities. The items available for IVA are:

- **Stabilizer**

  This is a device for berthing to a workpiece, for holding it in a preferred position to be worked on and for moving the workpiece relative to the MOTV. It is an articulated arm, mounted to the forward end of the crew capsule, between windows. Its length can be varied to suit a mission by adding or subtracting one of the articulating segments. At its tip is an end effector to grasp a fitting on the workpiece, thus mating the MOTV to the workpiece. Figure 1.5.1 shows typical application of the stabilizer.

- **Manipulator System**

  It is a master/slave manipulator system comprising two external slave arms, each operated from a master control within the cabin. The manipulators are bi-lateral force reflecting and they can be moved independently and concurrently. Each slave arm has seven degrees of freedom (DOF), these and the limits of motion are displayed in Fig. 1.5.2.

  Figure 1.5.3 shows a typical dexterous manipulator arrangement for both master and slave units. Overall length of the slave is provisionally set at 2.5M. The end effector design will be dependent upon the mission.

  The two slave manipulators are mounted to the structure which supports berthing/docking ring. A typical application for the manipulator system is shown in Fig. 1.5.1.

- **Viewing Window**

  It is intended that the work area shall be viewed directly by the manipulator operator and by the stabilizer operator whenever possible. Viewing angles, relative to the design eye, are shown on Fig. 1.4.1

- **T.V. Camera**

  If required, a TV camera may be mounted to the tip of one manipulator to examine something not easily seen by direct viewing.

1.5.1.2 Contingency EVA. It is recognized that unforeseen difficulities may arise to prevent completion of a task planned for IVA. Consequently two contingency EVAs are catered for one each IVA mission. Pressure suits are provided for both crewmen and, with no airlock, cabin atmosphere is pumped down and stored. In addition to these contingency EVAs, one emergency EVA is provided so that if both contingencies

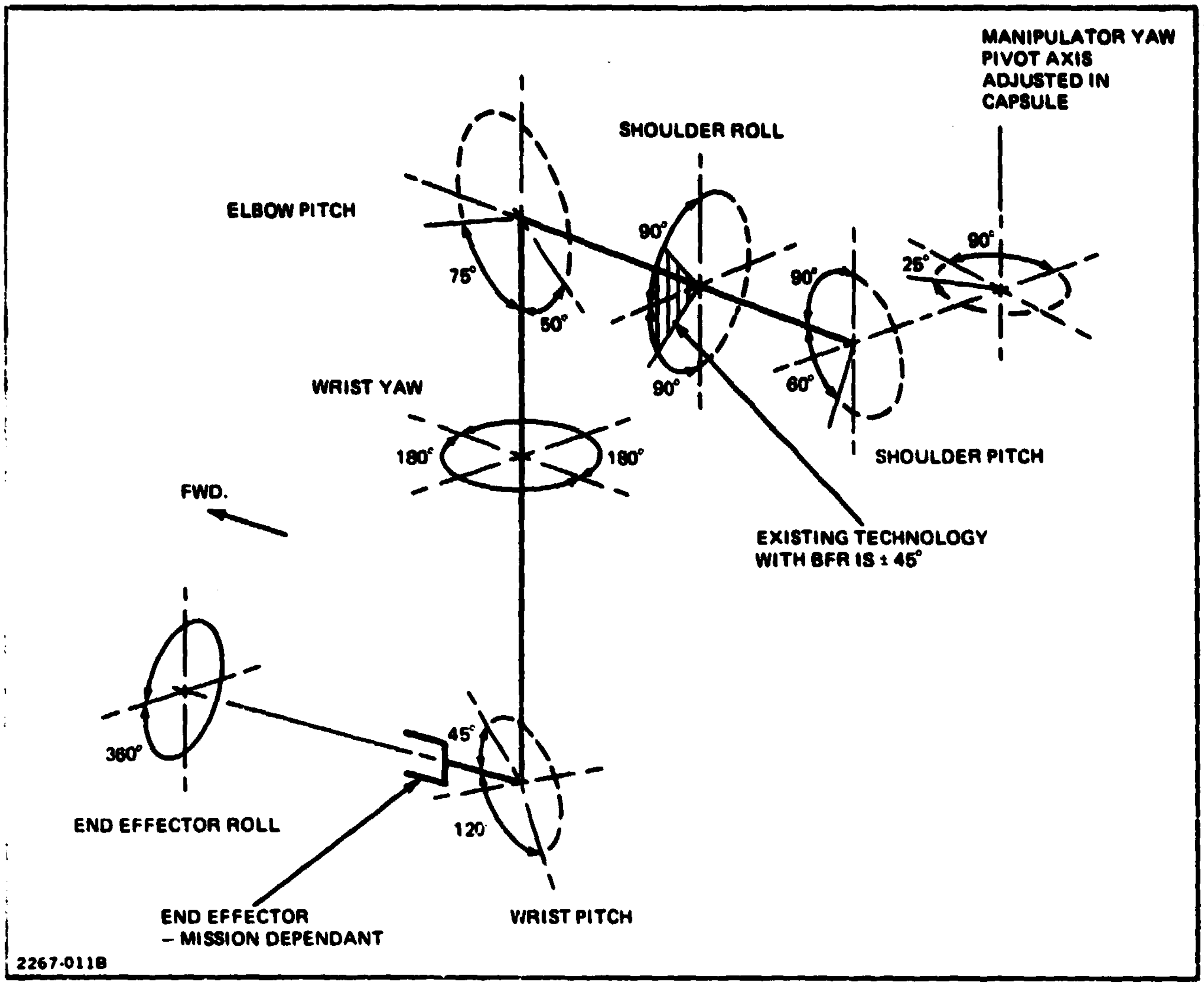


Fig. 1.5.2 Recommended Slave Arm Kinematics

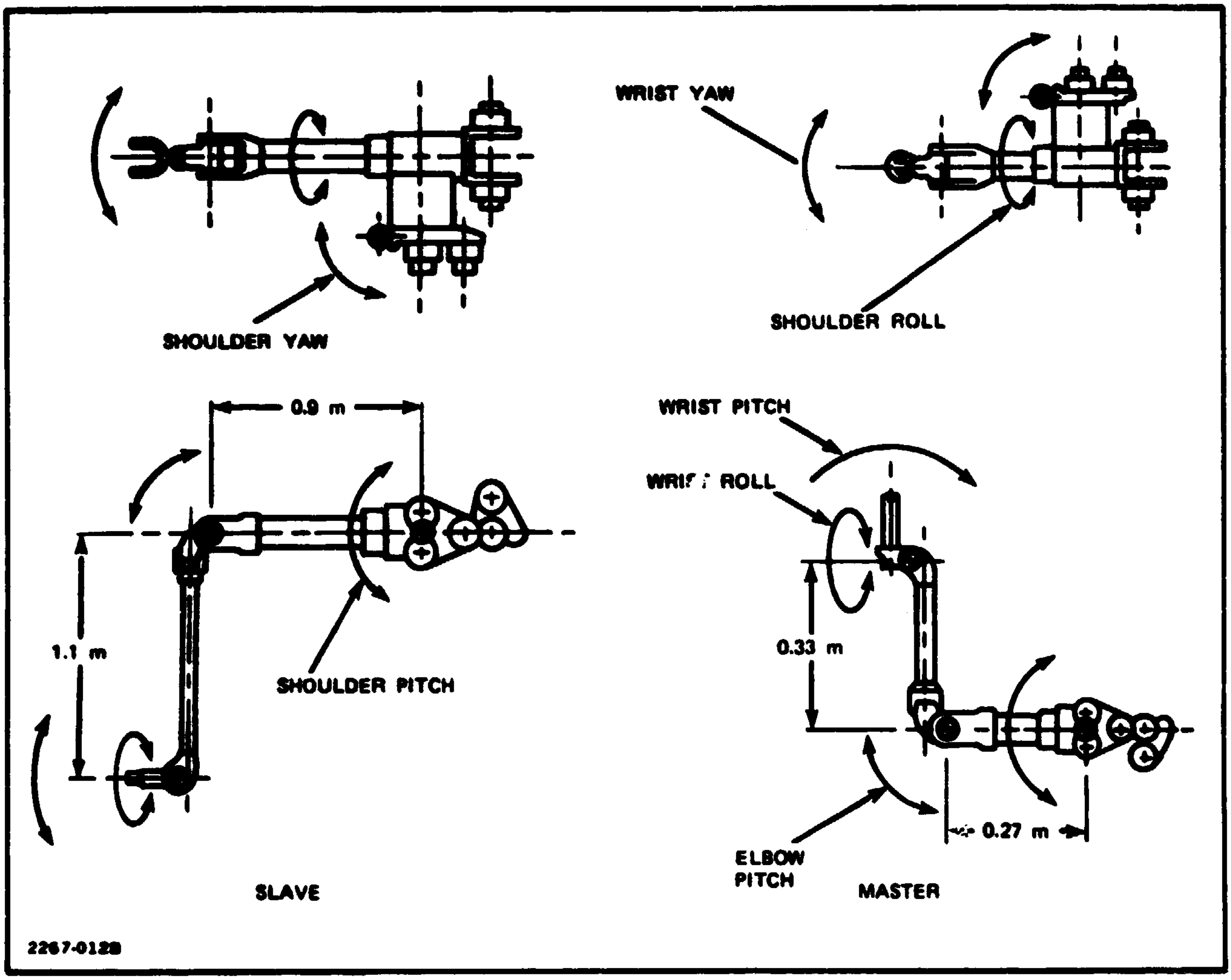


Fig. 1.5.3 Dexterous Manipulator Arrangement

are used on orbit, then there is always one EVA available for use in emergency during transfer to LEO.

1.5.1.3 IVA Productivity. Preliminary timeline studies of typical missions conclude that:

- Work periods of 9 hours per 24 hours are feasible.
- IVA performance times are
  - o 40% EVA times for short duration tasks
  - o 36% of EVA times for tasks requiring more than 1 work day

1.5.1.4 IVA Weight Penalty. To provide the IVA capability discussed in the preceeding paragraphs, including one emergency and two contingency EVAs, the following items with their associated weight penalties are required on each mission.

Equipment	
Manipulator system (2)	390 Kg
Stabilizer	50 Kg
GEO Pressure Suit (2) and support	295 Kg
Atmosphere pump down equipment	40 Kg
Atmosphere emergency tank	5 Kg
Δ Electronics	25 Kg
Consumables	
Pressure suits	59 Kg
Atmoshpere make-up	3 Kg
	867 Kg

1.5.2 EVA

The preferred method for performing mission tasks external to the capsule is to use IVA. Reasons for this preference are discussed in subsection 1.5.1. It is realized, however, that missions may arise where inaccessibility to the worksite or dexterity requirements mean that IVA cannot adequately perform the mission. It may require man's presence at the worksite to work directly on the task. EVA is, therefore, a method which must be made available to users of the MOTV.

The IVA mode recognizes this and provides for 2 contingency plus 1 emergency EVA on each of the missions planned to be all IVA (see subsection 1.5.1). Those EVAs will be performed with the participants tethered to the MOTV crew capsule which holds the workpiece in its stabilizer.

1.5.2.1 Tethered EVA. Missions requiring planned EVA activity can use tethered EVA for tasks which are within the capabilities of a tethered astronaut. Options for so performing EVA with a total crew of two are, firstly, one man goes out while the other remains in the capsule, but suited, ready to go to the assistance of his mate if needed, and secondly, both men go out to provide the full buddy system. They can control the capsule subsystems by voice recognition and synthesis.

An airlock will not be provided, therefore capsule atmosphere will be pumped down and stored for each EVA.

Weight penalties are given below for a 'mainly IVA' mission with some additional 'planned EVAs', over and above the 2 'contingency EVAs' discussed in subsection 1.5.2. Weights are also given for an 'all planned EVA' mission with no IVA. This latter mission has a tantalum shield lining the crew capsule wall to help compensate for the additional rem count expected when an EVA crewman is outside, not protected by the crew capsule. GEO EVA suit protection is limited by the need to provide adequate movement for performing mission tasks.

Weight penalties are:-

- Planned tethered EVA + IVA:

IVA weight penalty (Section 1.4.1)	867 Kg
Each planned EVA, over and above two	21 Kg

- All planned tethered EVA:

Stabilizer	50 Kg
Tantalum shield	340 Kg
GEO pressure suit (2) and support	295 Kg
Atmosphere pump down equipmt	40 Kg
Atmosphere emergency tank	5 Kg
Electronics	35 Kg
Consumables for 1 emergency EVA	21 Kg
	786 Kg
Consumables for each planned EVA	21 Kg

- Mission charged weight penalty for additional crew

  Added 'EVA' man = 137 Kg + 21 Kg per EVA

  Added 'Non-EVA' man = 8 Kg + 21 Kg per EVA

1.5.2.2 EVA Stabilized by Work Platform. Some mission tasks planned for EVA performance, may not be within the capabilities of an EVA crewman who is restrained by a flexible tether and, therefore, cannot react loads. A work platform, termed 'open cherry picker' (OCP), is proposed for these missions and is shown in Fig. 1.5.4. The OCP is supported by an articulated arm, perhaps an IVA manipulator, mounted to the crew capsule. The arm places the OCP into the work zone, as illustrated in Fig. 1.5.5.

The operational sequence is that, having berthed the MOTV to the workpiece by using the crew capsule stabilizer, the EVA man exits the crew capsule and boards the OCP, which is stowed close by the EVA hatch. He then operates OCP controls to guide and place himself where he wants to be for the mission task. As shown in Fig. Fig. 1.5.5, an OCP stabilizer mates the platform to the workpiece by a locking mechanism and, once that joint is rigidized, the joint between OCP and its support arm is softened so that the OCP is rigidly mated directly to the workpiece. He can now perform his task.

OCP facilities are called out in Fig. 1.5.4.

Weight penalties for this EVA mode are:-

Stabilizer	50 Kg
Open Cherry Picker	227 Kg
Tantalum Shield	340 Kg
GEO Pressure Suit (2) and support	295 Kg
Atmosphere Pump down equipment	40 Kg
Atmosphere Emergency Tank	5 Kg
Electronics	35 Kg
Consumables for 1 emergency EVA	21 Kg
	1013 Kg
Consumables for each planned EVA	21 Kg

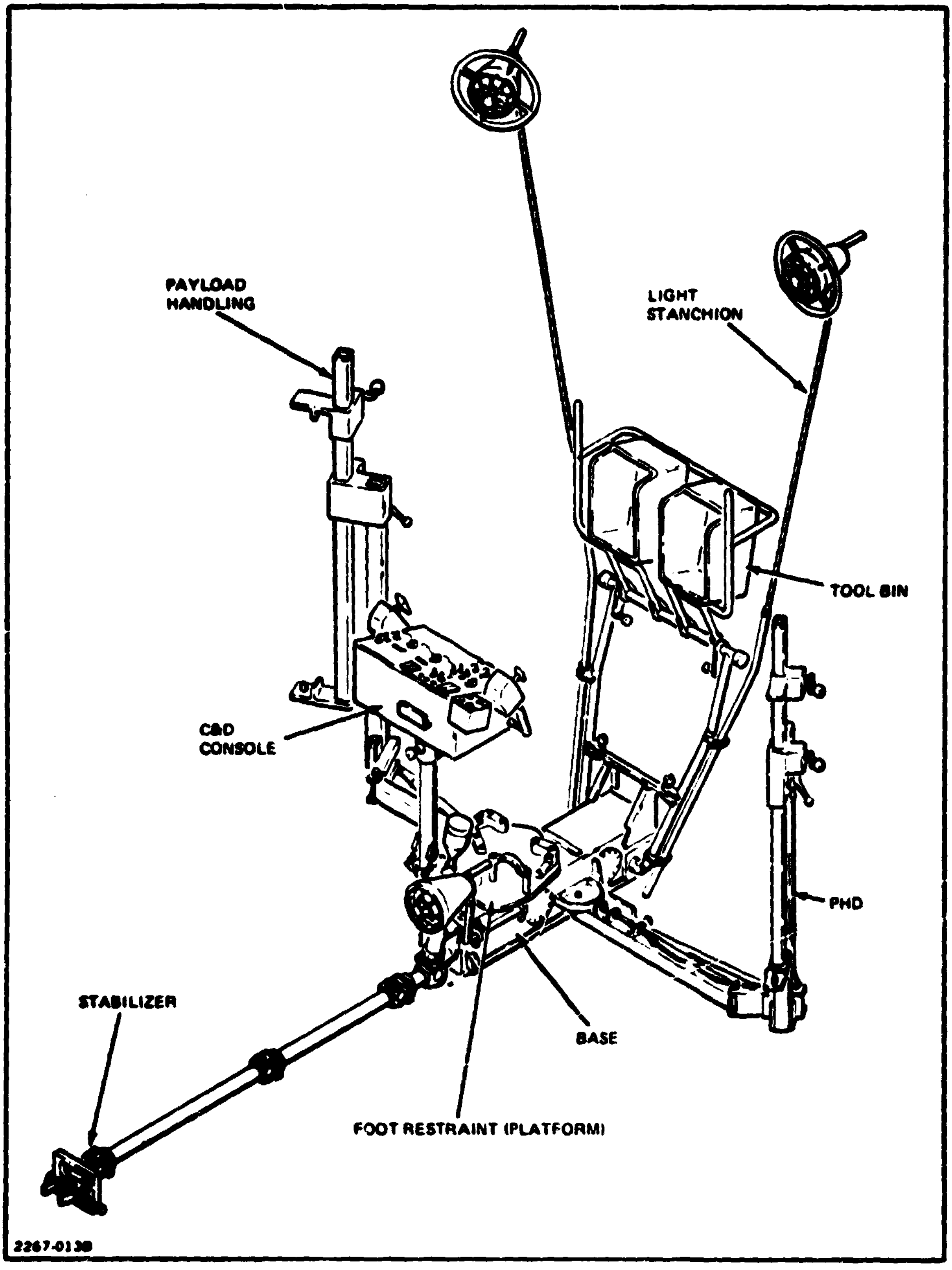


Fig. 1.5.4 Open Cherry Picker (OCP) Work Platform

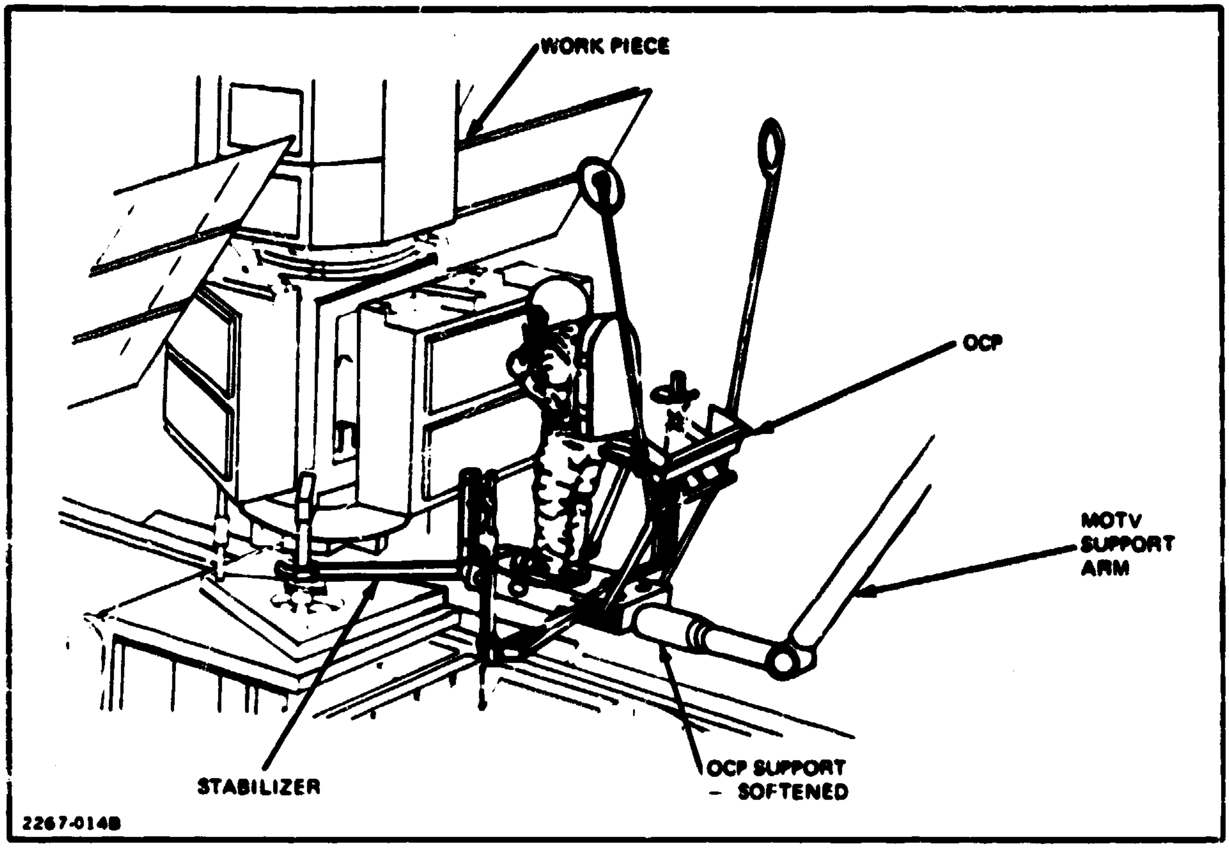


Fig. 1.5.5 EVA Performed Using OCP

Should an additional crewman be required on a particular mission, the weight penalty is:

Added 'EVA' man = 137 Kg + 21 Kg per EVA

Added 'Non-EVA' man = 8 Kg + 21 Kg per EVA

1.6 RADIATION PROTECTION

To satisfy requirements for protection of the crew from solar radiation during a GEO mission, the crew capsule and the GEO EVA suit are designed to provide the protection defined below. The dose rates are for conditions where flux per solar event does not exceed 1×10^9 protons (protons ≥ 30 mev). They apply to the skin, which is considered critical since bone marrow is somewhat protected by soft flesh, and the eyes and testes can have dedicated protection. The crew capsule and the GEO EVA suit are designed to provide the following protection:-

- Crew capsule restricts dose to:

  5 rem for one outward and one inward passage through Van Allen belts.

  0.4 rem per day on orbit at GEO.

- GEO EVA suit restricts dose to:

  14 rem for each 6 hour EVA at GEO, under '24 hour averaged' conditions.

For missions employing IVA as the method for performing external tasks, the crew capsule has outer epoxy tiles for the first barrier to inhibit proton production, then the aluminum pressure shell and, finally, an inner shield of tantalum which is efficient at blocking bremsstrahlung. The total wall has an effective equivalent thickness of 1.2 cm af aluminum.

With EVA, the pressure suit must be flexible enough to permit the performance of mission tasks. This dictates the materials, thicknesses and, consequently, the radiation protection it affords. To compensate in some measure for the radiation dosage that an EVA man will get while outside the capsule, an additional thickness of titanium shielding is provided in the crew capsule so that the astronauts career dose limitation is not reached too quickly.

Crew radiation limits for the MOTV use the permitted dosages currently defined for the shuttle crew.

With the crew capsule designed to provide protection for any event up to 1×10^9 protons/cm^2, a solar flux in excess of that level requires abandoning the mission and descent to below an altitude equal to three earth radii. To provide some margin of safety, a solar event forecast system is suggested and when a flux level of 1×10^8 protons/cm^2 is reached, the MOTV will retreat from geosynchronous orbit.

Missions may arise where this philosophy cannot apply. Firstly, a deep space crew rotation mission of about 14 days duration each way, where the vehicle can be too far out to retreat to a safe orbit. Secondly there are those missions with highly elliptic, 12 hour orbits which entail passing through the Van Allen Belts four times a day. The deep space mission will, and the 12 hour orbit may, require a heavier cabin wall or a storm shelter.

1.7 SUBSYSTEMS

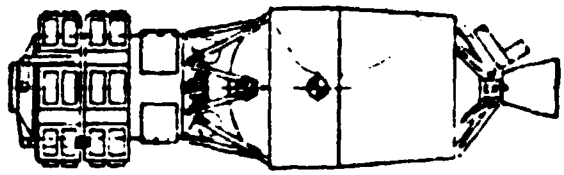
The main general objective for MOTV subsystems design is to support the crew adequately and to provide as much autonomy as practical to minimize dependance on mission control. The approach for the latter is to use advanced aircraft displays and controls concepts to read out vital parameters as a function of flight phase, to diagnose subsystem failure, to provide fault isolation and, finally, automatic switching to back-up operation modes for time critical functions.

Starting with unmanned missions, the vehicle (OTV) has subsystems necessary for its autonomous operations. When a manned mission is called for, a crew capsule is added to the configuration, together with necessary subsystems equipment, to make up the MOTV. In general this added equipment is located in and around the crew capsule but some of it, such as additional fuel cell propellants or a solar array, is added to the propulsion core where most of the OTV subsystems are located.

Figure 1.7.1 shows the subsystems added when converting from OTV to MOTV and their location. All are crew capsule related and are chargeable to crew capsule weight, as identified in Fig. 1.3.1.

When positioning these subsystem equipments on the crew capsule or on the propulsion core, there are certain considerations to be borne in mind: -

a) The vehicle c.g. should be located to minimize MOTV engine gimbal requirements and to suit the Oribiter c.g. envelope when MOTV components are launched to, or deorbited from, LEO.



	CREW CAPSULE	PROPULSION CORE
AVIONICS	DISPLAYS & CONTROLS DATA MGT TRACKING/TELE/COMM. NAV & GUIDANCE	RENDEZVOUS RADAR
POWER	CONV/DISTRIB	SOLAR ARRAY (SOME MISSIONS) FUEL CELLS & TANKS CONV/DISTRIB
THERMAL CONTROL	RADIATORS	FUEL CELL RADIATORS
ECLS	TEMP/HUMIDITY CONTROL CO_2 REMOVAL	
CREW ACCOM.	PERSONAL HYGIENE WASTE MGT FOOD PREPN	
EXPENDABLES	LIFE SUPPORT	FUEL CELL REACTANTS

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Fig. 1.7.1 MOTV "Crew Capsule Related" Subsystems Locations

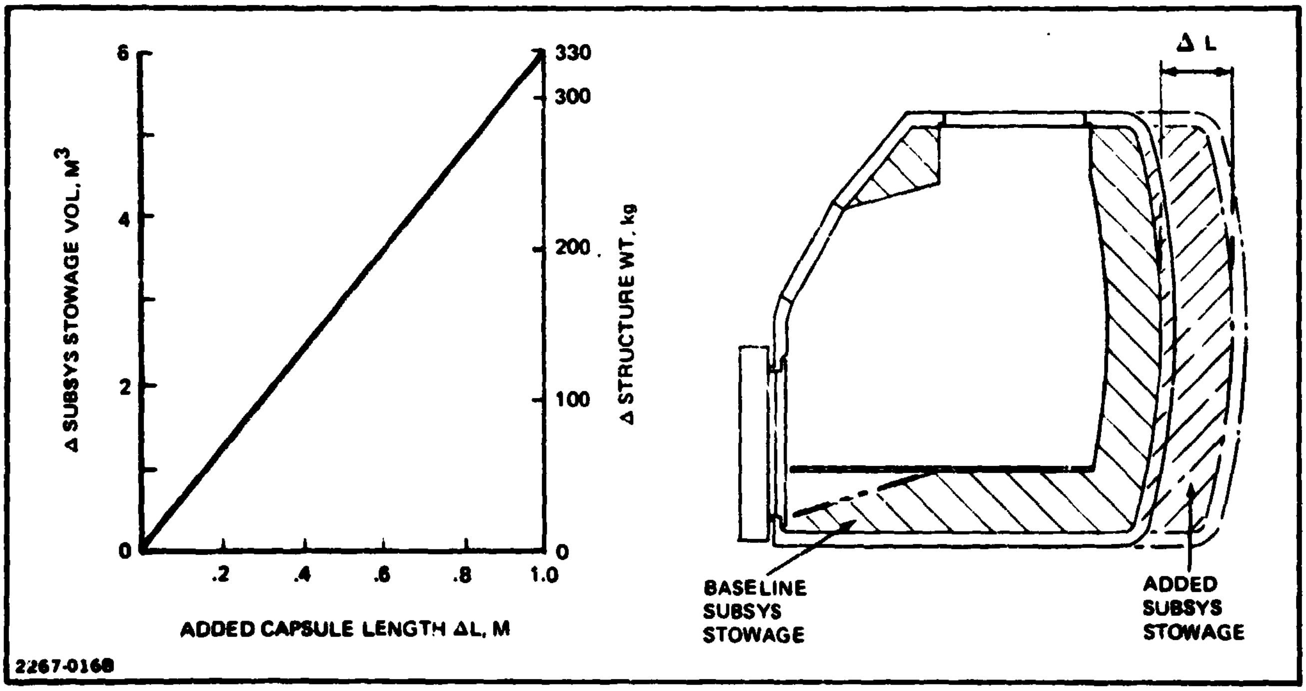

Fig. 1.7.2 Crew Capsule – Penalties for Providing Additional Subsystems Stowage

b) Subsystems should be accessible for on-orbit emergency repair/service and for ground maintenance to allow minumum turnaround times.

c) It is desirable to minimize the relocation of subsystems when going from OTV to MOTV and vice versa.

d) Safety dictates that, for instance, high pressure bottles should be mounted external to the crew capsule and, if possible, away from other vital areas.

Subsystem equipments mounted external to the crew capsule must not inhibit EVA ingress/egress from the capsule, nor must they obstruct the operation of the thermal control radiators or access by manipulators to mission equipments. Subsystem equipments mounted inside the crew capsule require a stowage volume of about $3M^3$. As these equipments are defined further, the volume may increase. Figure 1.7.2 shows the penalties for providing additional volume in the bank of subsystems located inside the aft dome (Fig. 1.2.2). To double the existing available volume, by adding $3M^3$, means an additional 0.5M of capsule length and an increase of 165 kg in structure weight.

1.7.1 Avionics

Overall command and control for a manned mission is shown in the schematic of Fig. 1.7.3. Inter-relationship of the various avionics subsystems is shown here.

The equipment, designed to monitor and control, consists of distributed microprocessors integrated with each remote terminal (RT) located with the subsystem hardware. Subsystem information is converted, and scaled, formatted and tested by the remote terminal before being sent to one of two redundant Central Processing Units (only one shown). Subsystem failures are sensed by the microprocessors, and alarm flags are set whenever as associated failure exists. Backup modes of operation can be easily preprogrammed into the RTS. All information transferred between the RT's and central processors is accomplished via a quad redundant Mux Bus. The prime advantage of this type of distributed system for MOTV is the future off-line development of each subsystem without the problems normally associated with subsystem integration into a centralized system. Subsystem changes and growth are easily accommodated.

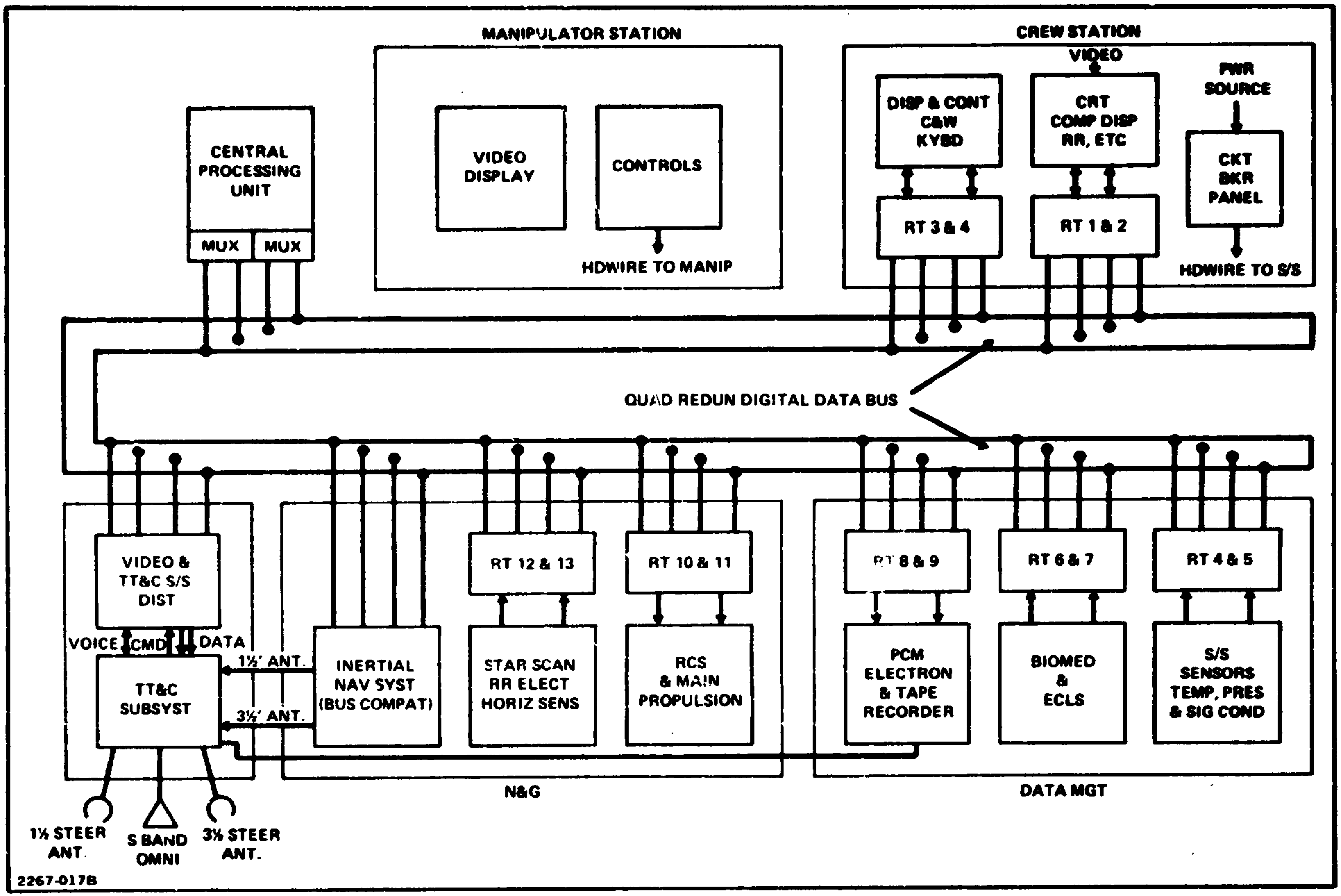

Fig. 1.7.3 MOTV Overall Command and Control System Schematic

1.7.1.1 Displays and Controls. This subsystem is added to the OTV for manned missions. A block diagram for this subsystem is shown in Fig. 1.7.4 The diagram shows the various controls and displays used in the capsule. Circuit breaker panels control DC and AC power. A display showing the output of the Caution and Warning Electronics will be used by the crew for malfunction identification. Closed Circuit T.V. (CCTV) Display is provided for IVA and the controls to operate the manipulators. A Computer CRT Display is used by the crew, along with a keyboard for calling up data stored in the CPU. A Data Distribution Center is provided for routing and switching the various electrical signals throughout the MOTV. Color T.V. is available from a hand held camera during EVA for display in the cabin, and for transmission to the ground along with CCTV pictures. A rendezvous radar display is used to show the range and bearing data from targets during the rendezvous operation.

1.7.1.2 Data Management. Adds to an existing OTV system to cater to manned missions. The additions are shown in the block diagram for a typical DM subsystem, Figure 1.7.5. This overall subsystem accepts status inputs from the various other subsystems, then signal conditions and converts them from analog to digital read-outs. These inputs are electronically sampled and converted to a data stream by the PCM Electronics. This data stream is sent to Telemetry, Tracking and Command Subsystem via the data distribution center for transmission to the ground. Caution and Warning Electronics is used to derive the Crew Caution and Warning (C & W) Display in the cabin. Bio-Med and ECLSS inputs are also displayed and transmitted to the ground. A tape recorder is provided to work in conjunction with the data distribution center for recording data and voice, and to playback to the ground as required.

1.7.1.3 Tracking, Telemetry and Command. For manned missions, adds little to the equipments required for OTV. The additions provide voice communication between crew stations in the MOTV and to outside manned activities. Equipments for this are radiated power indicators, a speaker and crew microphones.

1.7.1.4 Navigation and Guidance. Adds to an existing OTV System to cater to manned missions. Figure 1.7.6 shows a typical N & G subsystem block diagram and identifies equipment to be added for a manned mission. The overall subsystem shows the IMU providing attitude information to the CPU via the DIU. The Star Scanners are used to provide star-angle measurements for alignment of the IMU. A Horizon Sensor is used to provide redundant attitude information to the CPU. Crew Navigation displays

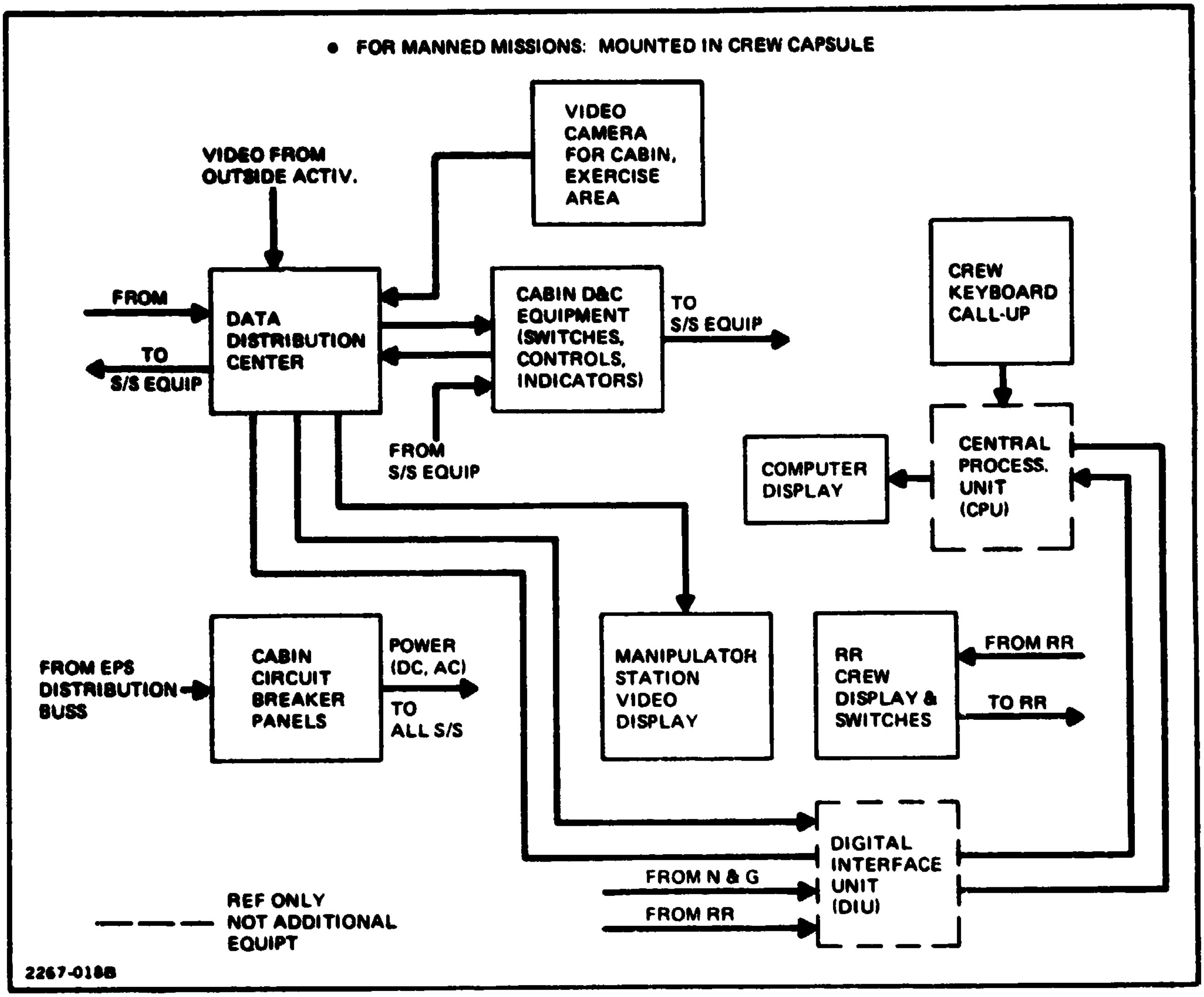

Fig. 1.7.4 MOTV Display and Control Subsystem

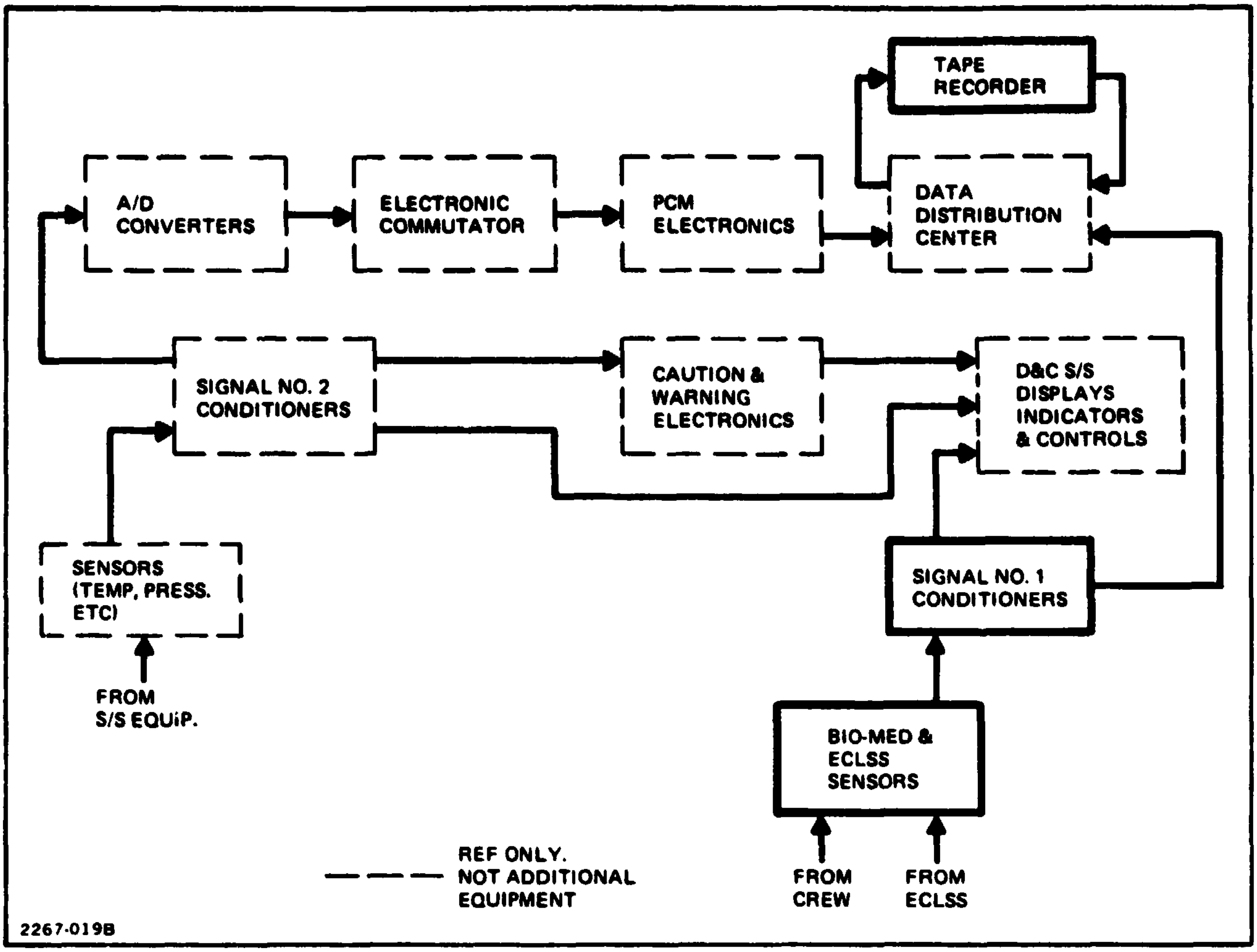

Fig. 1.7.5 MOTV Data Management Subsystem – Added Equipment

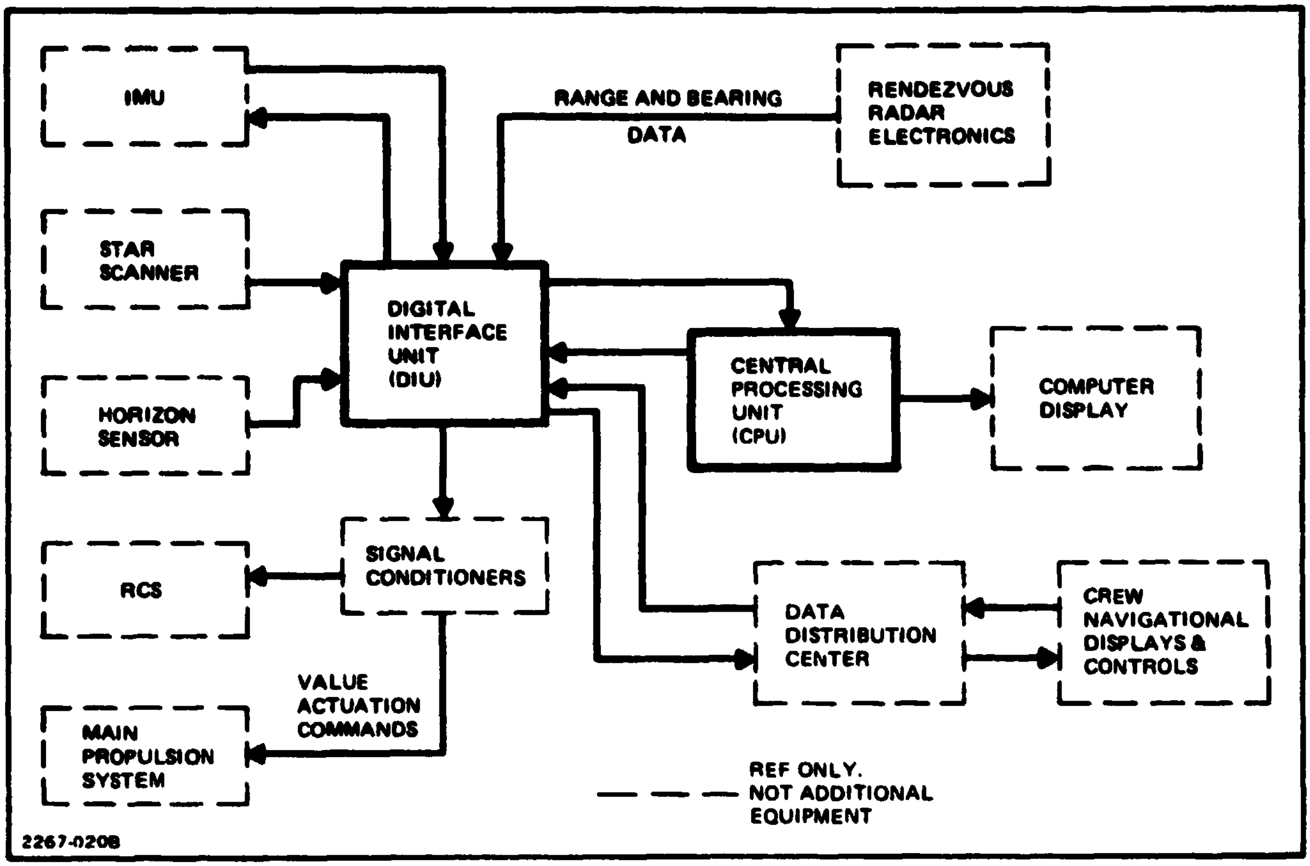

Fig. 1.7.6 MOTV Navigation and Guidance Subsystem – Added Equipment

and controls are used for automatic and manual control capability for all mission phases. Guidance commands that drive control loops are generated to actuate valves in the main propulsion system and the RCS.

1.7.2 Electrical Power

The subsystem to provide this power is located entirely in the propulsion core. The crew capsule, when it is added for manned missions, has only the electrical interface with the core and its own distribution network.

The range of mission electrical energy requirements for the 5 design reference missions, varies from 350 KW hr. for a 4 day mission to 1274 KW hr. for a 19 day mission to 2000 KW hr. for a 26 day working mission. These energy levels each includes a 4 day reserve.

Since a manned mission uses the EPS provided by the OTV, manned subsystems requirements should be borne in mind when considering candidates for that system. As an input to that evaluation, a trade was performed to consider combinations of EPS and ECLSS weights for various options to determine the lightest combination. These two subsystems are inter-dependant in as much as they share a common interest in the use of water from fuel cells for life support and the sharing of oxygen. It was found that, for most prospective missions, the lightest combination was open subsystems of the type used on the shuttle. That is, open fuel cells for EPS and oxygen and potable water supply to the ECLSS. CO_2 removal from the ECLSS uses LiOH. For missions with power requirements beyond the capability of the baseline fuel cell system, a solar array is added to provide half the on-orbit power requirements. The array is mounted on the propulsion core, close to the rest of the EPS equipment.

1.7.3 Environmental Control and Life Support

As discussed in section 1.7.2, this is an open type subsystem using LiOH for CO_2 removal. Since the primary electric power source is fuel cells, water produced by the cells is used for drinking and breathing oxygen is carried as part of the fuel cell supply. A schematic of this subsystem is shown in Fig. 1.7.7.

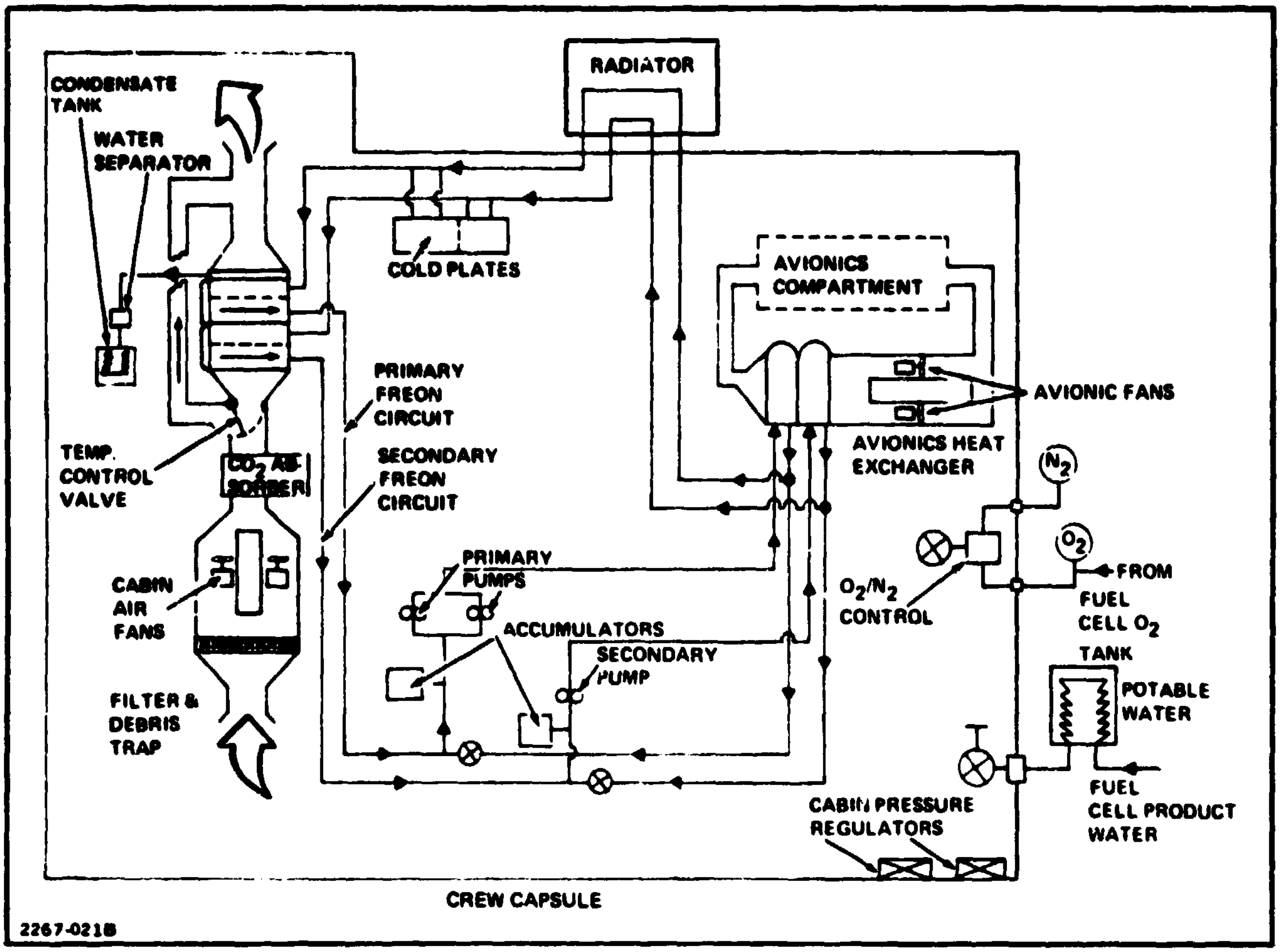

Fig. 1.7.7 MOTV ECLS Baseline Schematic

	HEAT LOAD	
	MAX	MIN
AVIONICS	800 W	300 W
ECLS	570 W	570 W
METABOLIC	273 W	140 W
STRUCTURE	-41 W	-41 W
NET LOAD	1602 W	969 W
TEMP LIMITS		
INLET	66°C	30°C
OUTLET	16°C	10°C

RADIATING AREA = 7.25 M^2

- ONE VARIABLE CONDUCTANCE HEAT PIPE RADIATOR
- RADIATOR CAPACITY LOSS PER METEORITE STRIKE > 10%
- FREEZING TEMP BELOW -130°C (-202°F)
- STRIP HEATERS FOR THAW OUT – THAT OUT TIME NOT TO EXCEED 1 HR

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Fig. 1.7.8 Crew Capsule Radiator Sizing

1.7.4 Thermal Control

The radiator for dissipating heat loads from avionics, ECLS and metabolic heat is sized to reject the required 1.6 KWh irrespective of crew capsule orientation. ' A breakdown of this load is given in Fig. 1.7.8. Radiating area is $7.25M^2$.

1.7.5 Crew Accommodation

The crew capsule provides $3.0M^3$ of free volume for each crew member in a single deck layout, see Fig. 1.2.2. Each crew member has an adjustable restraint at his work station. This restraint also supports him when resting in his curtain enclosed area. Storage volume of $0.2M^3$ is provided in that area for his personal belongings.

The galley is capable of storing and heating foods as well as heating water. It is the unit supplied for shuttle operations.

Personal hygiene provides a unit containing his personal grooming aids and a body washing station, such as that proposed for the space shuttle.

Body waste collection uses the facility proposed for the space shuttle.

Off duty equipments include audio/visual systems, books and for longer mis-missions, exercising equipment.

EVA suits are donned in the 1.12 m x1.12m area bounded by galley, waste management, aft subsystems and the work stations. This is ample area for the suits to be donned one at a time. The hard upper torso of the two suits are stored as shown in Fig. 1.2.2. The suit drying and servicing equipment is located with the rear subsystems.

1.7.6 Consumables

Consumables related to manned missions are stored mainly in and around the crew capsule. Those which do not require access during a mission, in particular high pressure bottles and other safety influenced items, are stored external to the capsule within the interface structure mounting capsule to propulsion core. A four (4) day reserve is carried on all missions.

Additional fuel cell reactants attributable to the manned mission electrical power requirements are carried in the propulsion core, close to the fuel cells.

A breakdown of consumables to be carried for a manned mission is: -

• Atmosphere leakage make up	1.0 Kg/day
• Oxygen usage	0.84 Kg/Man day
• Emergency oxygen	10 Kg
• EMU expandables	6 Kg/Man/EVA
• LiOH	1.2 Kg/day
• Food	1.45 Kg/Man day
• Clothing	0.8 Kg/Man/Day
• Personal hygiene materials	0.5 Kg/Man/Day
• Fuel Cell reactants	Mission dependant
• Reserves	For 4 days

1.8 EXTERNAL STOWAGE PROVISIONS

The crew capsule package for performing mission tasks by using IVA includes equipments and facilities mounted external to the capsule, together with some subsystems equipments. Equipments for the DRMs are listed in Section 3 and Fig. 1.2.1 shows the external equipments and their locations. The capsule directly mounts slave manipulators, stabilizer, docking/ berthing, EVA hatch and such necessary subsystems equipment as radiators and high pressure bottles. Where there is room, without impairing viewing or operation of facilities, mission equipment is also mounted to the crew capsule.

With ground turnaround of MOTV missions, the shuttle transports the vehicle to and from LEO. It follows, therefore, that equipment mounted to the crew capsule must not inhibit stowage and deployment from the orbiter cargo bay.

1.8.1 Stabilizer and Manipulator

Subsections 1.2.1, 1.4.2. 1.4.3 and 1.5.1 describe the manipulator system and the stabilizer within the context of vehicle configuration and IVA mission performance.

The stabilizer, mounted to the capsule between viewing windows, berths the MOTV to its target work piece and holds the two bodies for the manipulators to perform their tasks. It can also maneuver the workpiece to assist with the mission task.

The two slave arms of the manipulater system, Fig. 1.5.3, are mounted to structure at the forward end of the crew capsule. This structure also supports MOTV docking. The manipulators reach back along the crew capsule body to pick up mission equipments and to transfer them to their installation/assembly/replacement location on the work piece. They then perform the task.

During MOTV transport to LEO in the orbiter cargo bay, the stabilizer and manipulator arms are stowed in positions which do not add to vehicle overall length.

1.8.2 Berthing and Docking

Figure 1.8.1 illustrates alternate methods for mating the MOTV to the orbiter and to other orbiting bodies.

Considering berthing, this is defined as a mating operation where a manipulator on one body captures the other body, then gently mates them. A manipulater is always flown on the shuttle, therefore berthing is available for that mating. With MOV mating to another body, if there is no crew transfer between them, then berthing can use the MOTV grappler to capture the other body and hold it. When crew are to be transferred and the target has a manipulator, then the target captures the MOTV and berths the two bodies at a sealed interface. This interface is a berthing ring on each vehicle and it is shown in Fig. 1.8.2. It is mounted to the forward end of the crew capsule to give unobstructed approach and mating. If the target does not have a manipulator and berthing is proposed for mating the two bodies, then the MTOV flies the manipulator and is active in the berthing.

The alternative to berthing is docking. Here, one vehicle flies into the other vehicle until mechanisms latch and hold the vehicles together. If the mission requires docking to the target, then the orbiter must carry a docking ring to match that on the MOTV. They may, however, be berthed together, using the RMS, rather than hard docked. The docking operation is only used for crew transfer and when there is no manipulator available on the orbiting target or the MOTV. Either the target is active and flies into the MOTV or vice versa. A typical docking ring is shown in Fig. 1.8.3. Its mounting is interchangeable with that of the berthing ring.

The docking ring is heavier than the berthing ring because it is more robust since it must take impact loads, its mechanisms for latching and pull up are more complex and it has attenuation in its mounting/support struts. Weights allocated to the two rings are: -

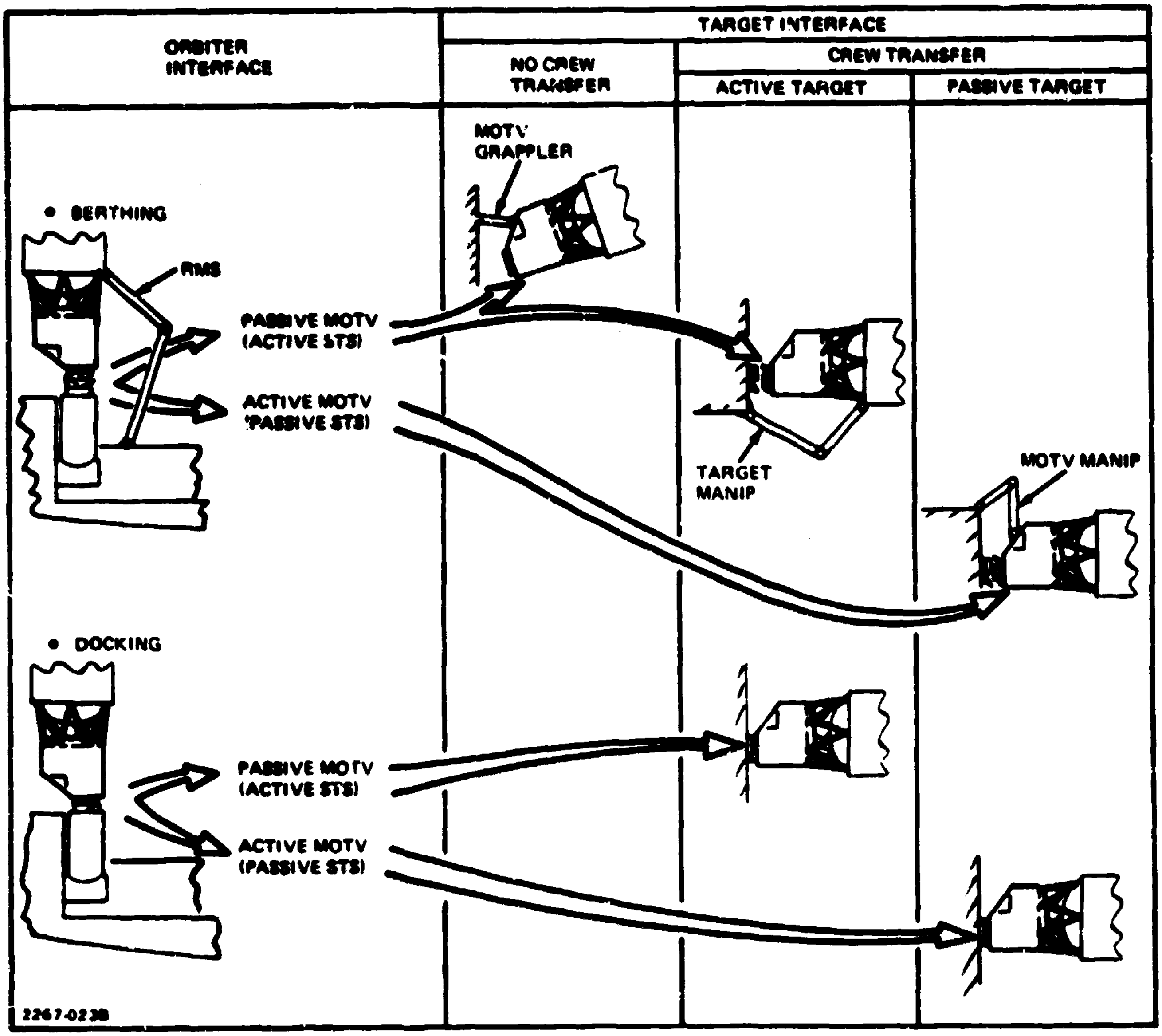


Fig. 1.8.1 Berthing/Docking Options

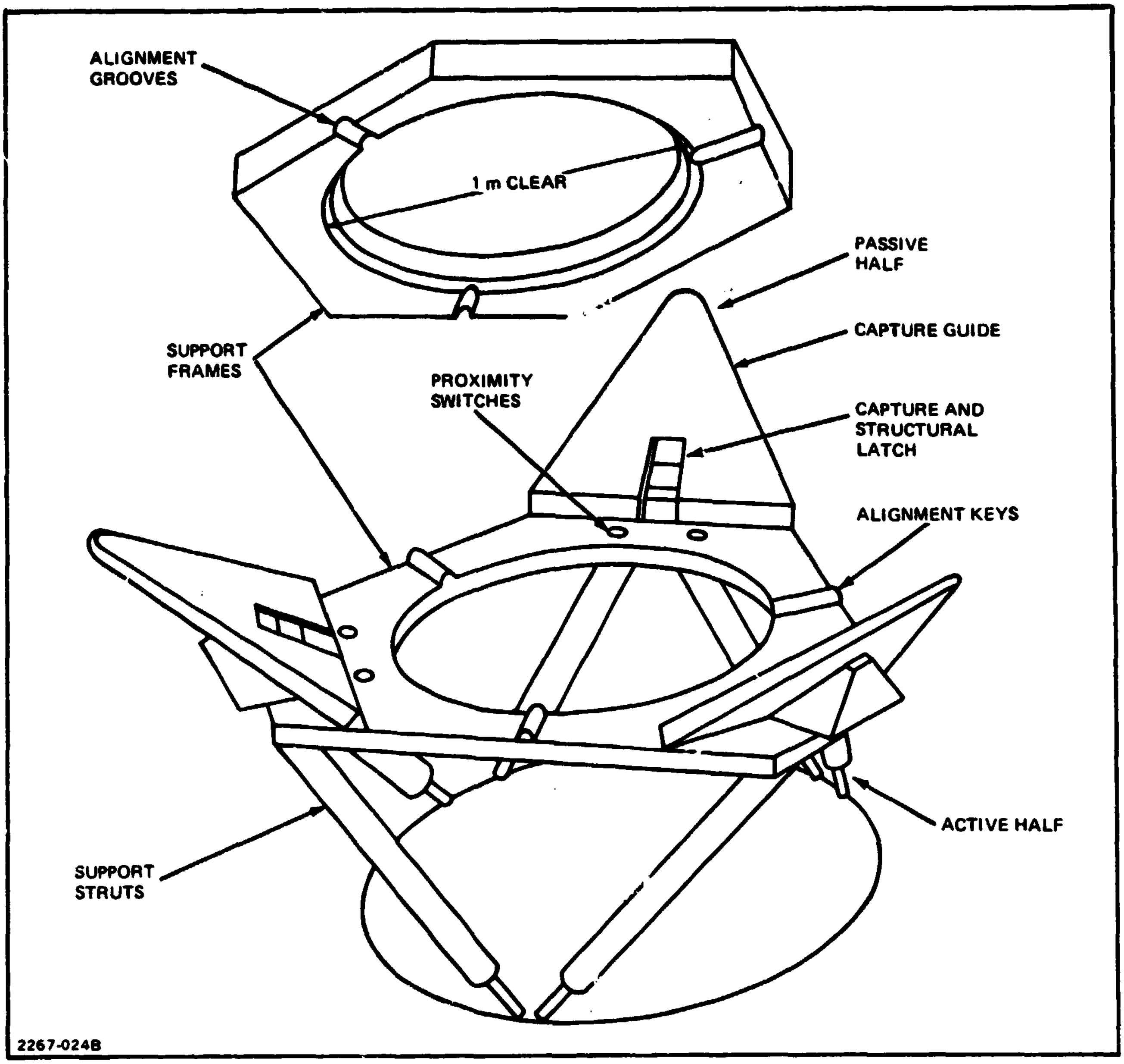


Fig. 1.8.2 Berthing Ring Configuration Interface Mechanism (BRIM) – McDonnell Douglas Configuration

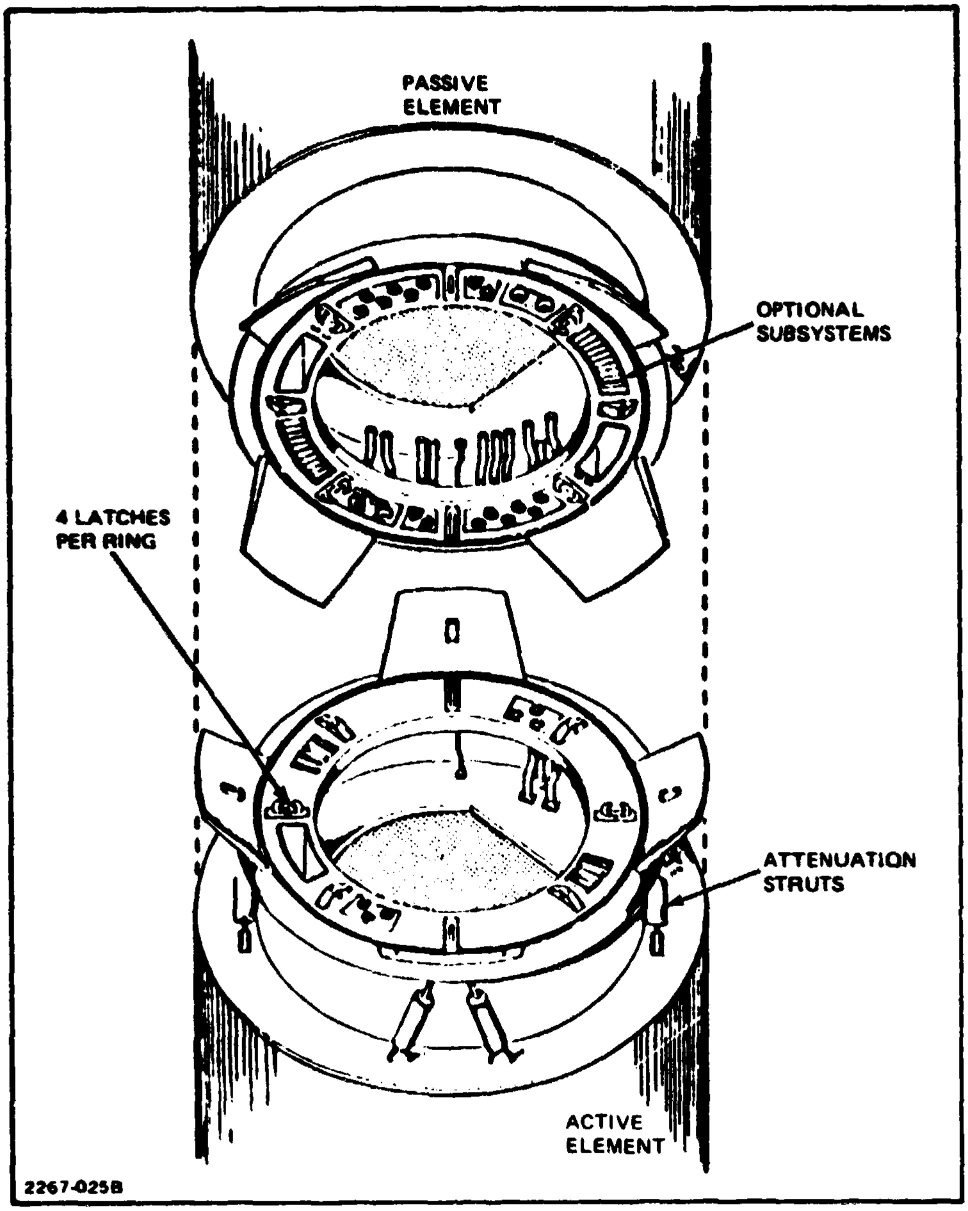


Fig. 1.8.3 Docking Interface – Rockwell Configuration

- Berthing ring = 110 kg
- Docking ring = 408 kg

The appropriate weight is included in "structure" weight, Fig. 1.3.1.

1.8.3 Subsystems External Equipment

These mountings have been discussed in subsections 1.2 and 1.7. In general they are the thermal control radiator which must radiate directly to space, the EVA hatch for EVA ingress and egress and the subsystems equipment, such as high pressure bottles. stored externally for reasons of safety. The radiator may be deployable if insufficient area is available to mount it directly to the capsule shell as a single sided radiator. The EVA hatch is in the cylindrical section of the crew capsule. Other subsystems equipment is mounted to the interface structure between crew capsule and propulsion core.

1.8.4 Mission Equipment

These equipments are included in the listings of Section 3. They fall into one of two categories, General Purpose Mission Equipment (GPME), which is of use on more than one mission, and Dedicated Mission Equipment (DME), which is peculiar to one mission.

GPME mounted external to the crew capsules covers such items as manipulator end effectors; EVA tools; diagnostic, calibration and check-out equipments. These items occupy little volume and for now, it is assumed that they will be stowed in spare pockets between larger equipments.

DME, on the other hand, includes the components for assembly, construction, replacement or servicing of a satellite, and the structures on which the components are mounted for transportation. It also includes, for want of a classification, RCS replacement propellant. For many missions, all of the DME can be attached to rails attached to the crew capsule shell. Figure 1.8.4 shows the volumes available, external to the crew capsule, for direct mounting of mission equipment. Subsection 1.9.2, MOTV/Orbiter interfaces, and the associated Fig. 1.9.4, discusses the mounting of mission equipments within the context of their effect on MOTV stowage in the orbiter cargo bay.

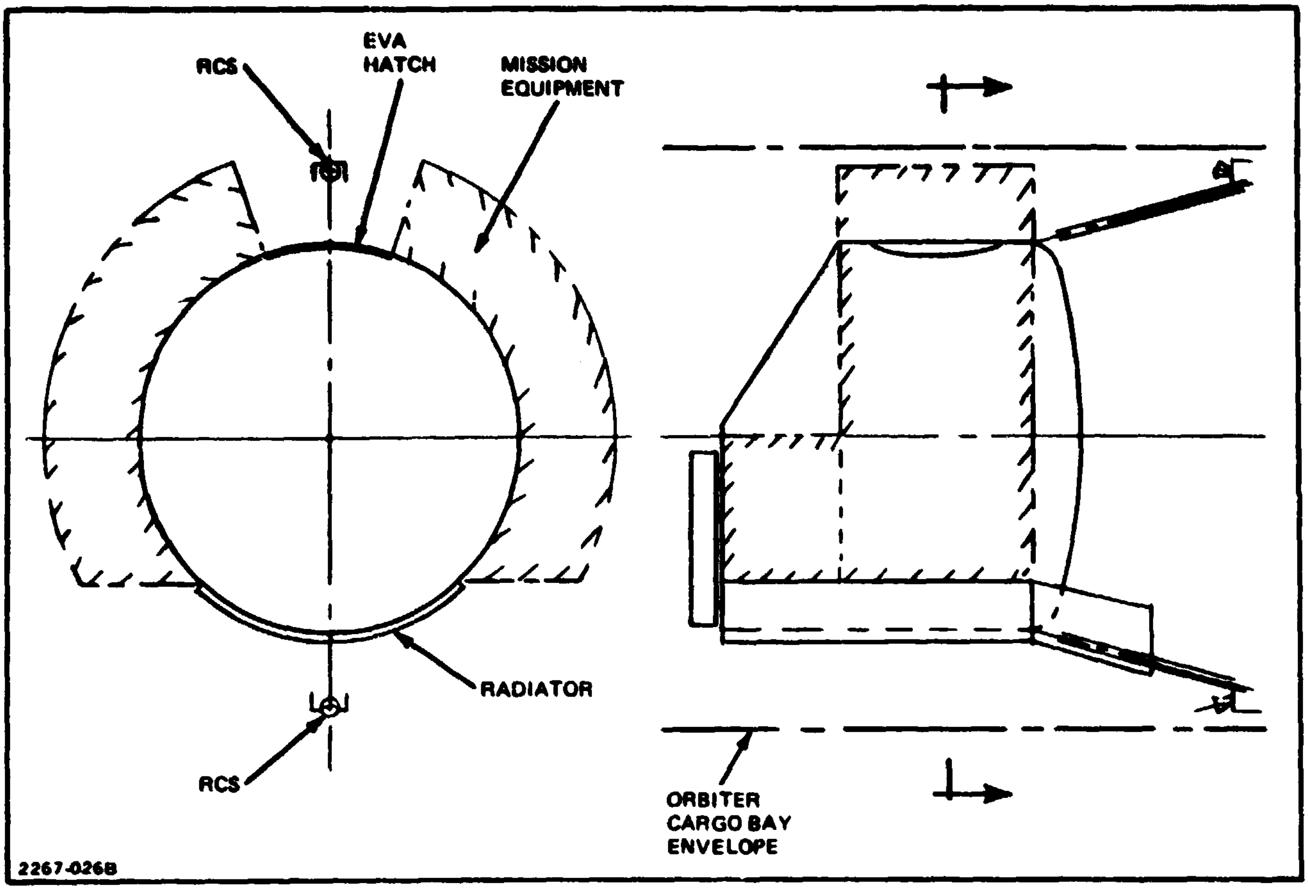


Fig. 1.8.4 Mission Equipment External Stowage

Other missions have too much DME for it all to be attached directly to the crew capsule. These extra equipments require separate support in the orbiter cargo bay during launch to LEO. In that orbit, they will be transferred by the orbiter RMS to their stowage on the MOTV. These stowage mounts will vary from mission to mission and, therefore, have not been defined. Again, reference should be made to subsection 1.9.2 and to Fig. 1.9.4.

1.9 INTERFACES

Physical interfaces occur between the crew capsule and the propulsion core, between the MOTV and the orbiter and between the MOTV and an orbiting satellite to which it is berthed or docked. Other interfaces are, typically, data transmissions to Mission Control on the ground (or SOC) and tracking signals between ground stations and MOTV.

1.9.1 Crew Capsule/Propulsion Core

Unmanned missions mount an inert payload to the propulsion core (OTV) which has an autonomous capability for performing the mission. When a crew capsule is added for a manned mission, the interfaces include structural support and hard wires for electrical power and manned mission related avionics, (see Fig. 1.9.1).

Structural interface is presently envisioned as being a truss structure, designed to support the crew capsule with its mounted equipments as a cantilever from the propulsion core. Since this configuration is the structural support system during Shuttle transport to and from LEO as well as during orbital operations, then the design case for the truss structure is to satisfy the requirements of "Space Shuttle System Payload Accommodations" document JSC07700 Vol. XIV.

Electrical power is generated entirely in the propulsion core, then routed to the crew capsule via hard wire interface.

Avionics subsystems are necessary for the OTV unmanned missions but they have additional equipment in the crew capsule for manned missions. In general, these subsystems interfaces carry signals both ways, hence the two headed arrows in Fig. 1.9.1. Rendezvous radar is mounted in the propulsion core and provides a read out in the crew capsule. Data management reports subsystems status to the propulsion core for transmittal to Mission Control Monitoring.

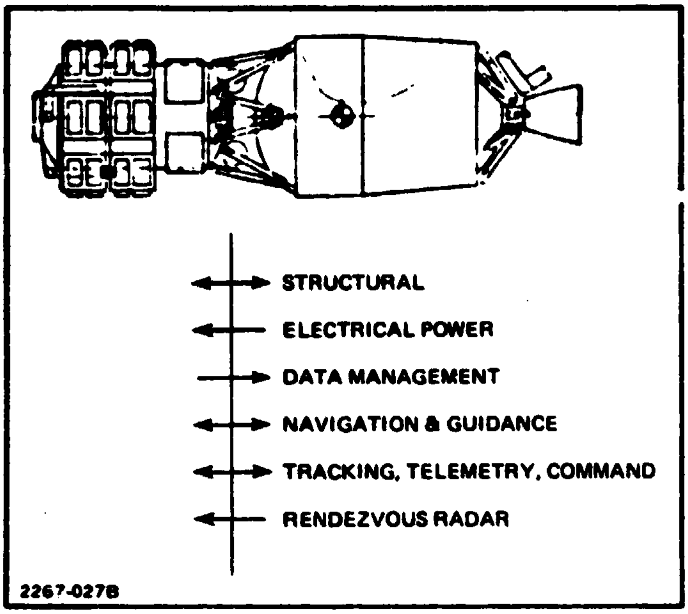


Fig. 1.9.1 Propulsion Core Support of Crew Capsule

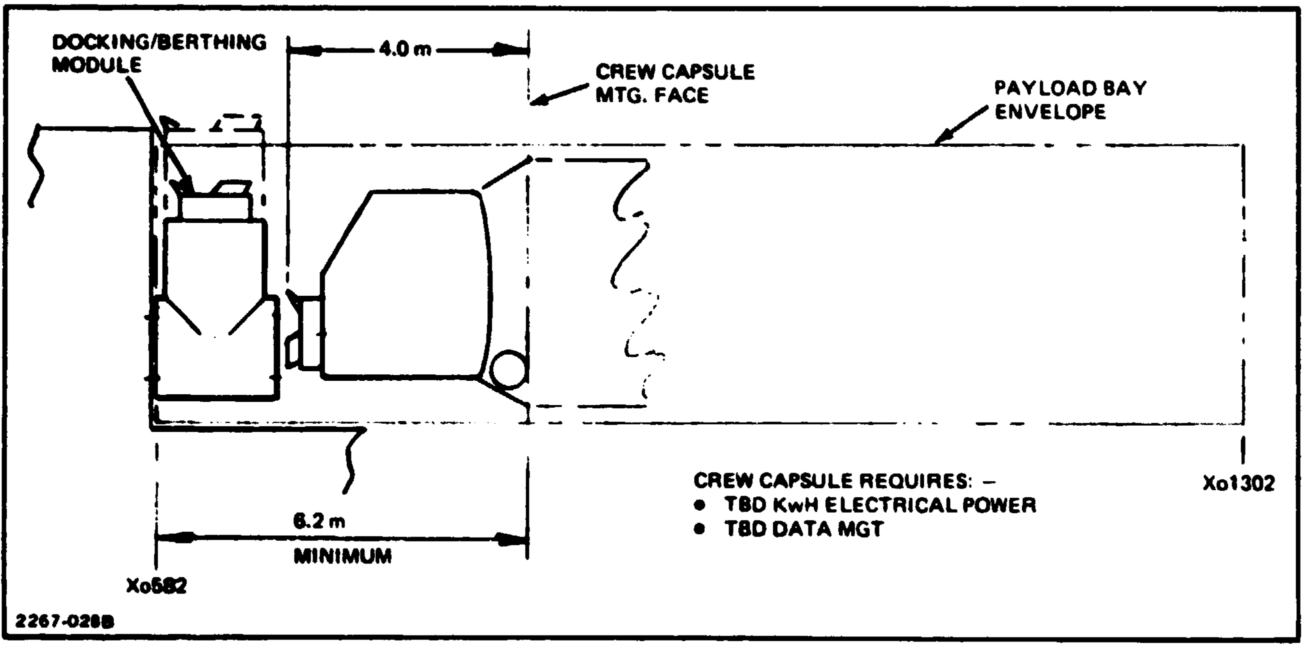


Fig. 1.9.2 Crew Capsule Stowage In Orbiter Cargo Bay – Baseline Concept

1.9.2 MOTV/Orbiter

There are two occasions when the MOTV requires physical support from the orbiter. The first occurs when the MOTV is stowed in the orbiter cargo bay and the second is when MOTV is docked/berthed to the standard docking module.

When in the cargo bay, the crew capsule is structurally supported as discussed in subsection 1.9.1. Baseline configuration for stowage in the cargo bay is shown in Fig. 1.9.2 where the orbiter standard docking module occupies the front of the bay, then comes the crew capsule to make a minimum total length requirement of 6.2M, leaving 12.0m for the propulsion core. This assumes that no cargo bay length is required for stowage of MOTV mission equipment. Other support for the crew capsule from the orbiter is electrical power for heaters, etc. and data management for monitoring MOTV subsystems status.

In this baseline concept, crew transfer to and from the MOTV crew capsule occurs when the MOTV is berthed to the orbiter docking module, as indicated in Fig. 1.8.1. This happens when the MOTV is deployed from the orbiter cargo bay, then berthed, and when MOTV returns to the orbiter from a mission and is berthed. Here, the only interface is that of the mating of the berthing rings. The docking module also serves as an airlock for orbiter crew EVA and for bridging the pressure differential between the orbiter cabin (14.7 psi) and the MOTV crew capsule (8 psi) when MOTV crew transfers in shirtsleeves. No prebreathing is necessary for this pressure differential.

Alternatives to this baseline crew transfer concept are shown in Fig. 1.9.3. The upper concept uses a GFE tunnel adapter for shirtsleeve access to a dedicated tunnel connecting the tunnel adapter to the crew capsule. A GFE external airlock is mounted to the tunnel adapter for orbiter crew EVA and for bridging the pressure differential when transferring shirtsleeve crew between the two bodies. The overall length required for this installation, including crew capsule, is 7.35m. The center concept has a dedicated tunnel which includes an emergency EVA hatch. This tunnel connects the internal orbiter airlock to the crew capsule, the overall length requirement is 6.25m. The lower concept is similar, except that the tunnel has no EVA exit. Instead, if the MOTV is stowed in the orbiter cargo bay, then emergency EVA for orbiter crew is via the MOTV crew capsule EVA hatch. This concept gives the shortest overall length, 5.25m of cargo bay required for crew capsule stowage.

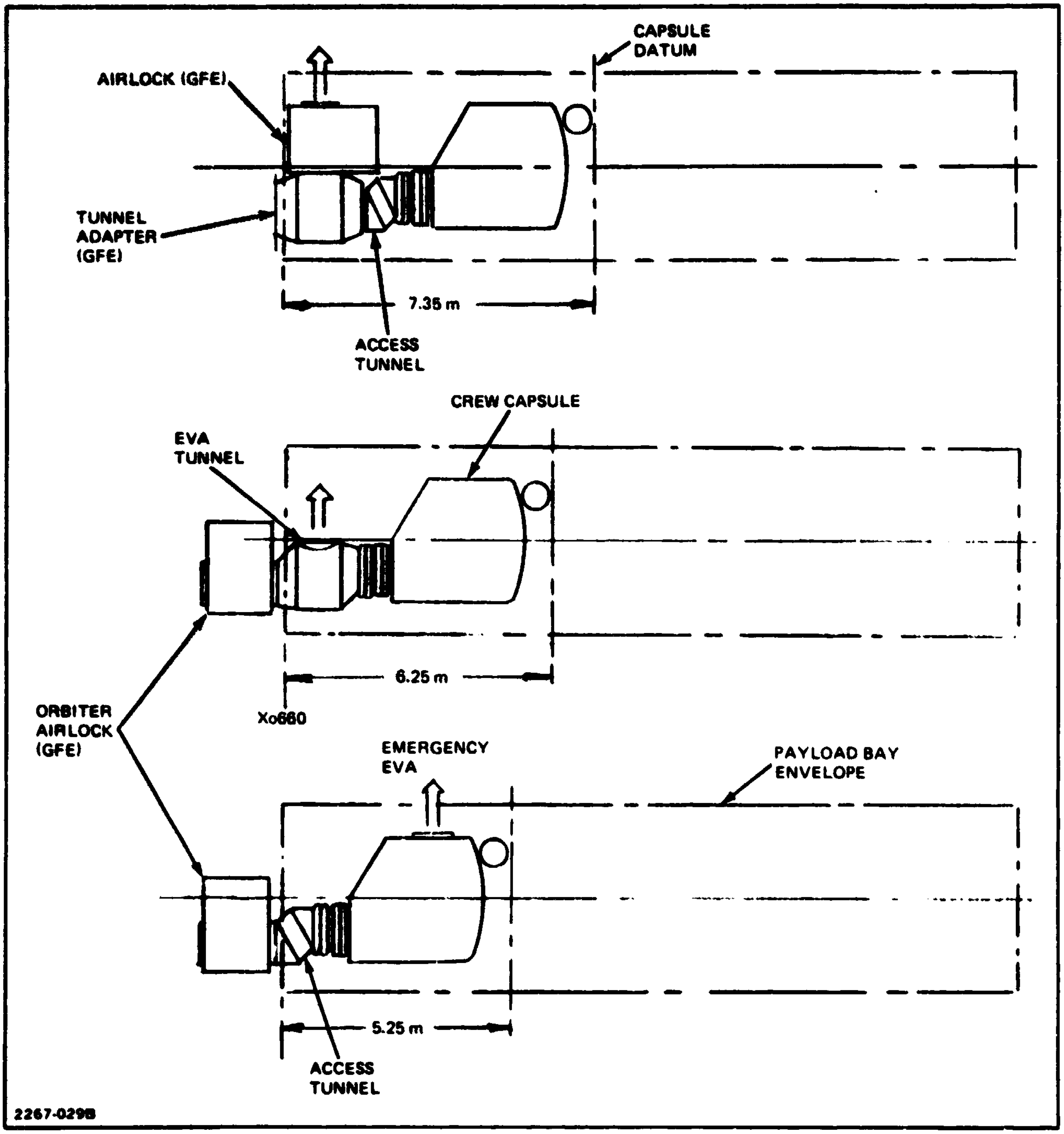


Fig. 1.9.3 Crew Capsule Stowage in Orbiter Cargo Bay – Alternate Concepts

One drawback to the tunnel interface concept is that, when there is a lot of mission equipments or hardware to be carried, then the crew capsule/MOTV may need to be located further aft in the cargo bay to make room for these equipments. The tunnel then will vary in length from mission to mission. Also, the orbiter payload c.g. envelope may require the MOTV to be located aft in the bay, thus leading to a longer tunnel.

MOTV mission equipments and hardware vary from mission to mission and they are discussed in subsection 1.8.4. The sizes of these equipments are restricted mainly by the cargo bay diameter and by the need to conserve bay length. In some cases mission hardware is folded for that very purpose. Figure 1.9.4 shows, for each design reference mission, the length of cargo bay diameter required for these components.

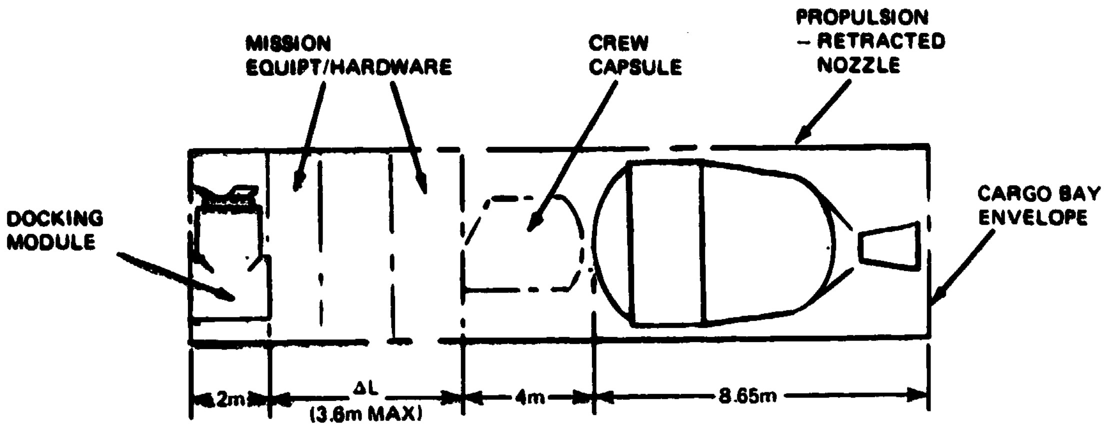
A crew capsule is always mounted forward of the propulsion unit, and with its attachments, a two man capsule takes up 4m of cargo bay length. Some mission equipment and hardware can be mounted around the capsule diameter and, for some missions, all of these items can be so accommodated. Other missions require additional cargo bay length and this is shown as ΔL for which the maximum available is 3.6m. The lengths comprising ΔL cannot be divided further without a lot of on-orbit assembly. To leave sufficient cargo bay length to stow a propulsion core/crew capsule assembly, it will be necessary on mission C3 to launch some mission equipment or hardware with a drop tank launch, then transfer the equipment to its mission mount when assembling the drop tanks to the propulsion core in LEO.

1.9.3 MOTV/Orbiting Satellite

For near term missions, the only interface will be the physical mating described in subsection 1.8.2, berthing and docking, and its accompanying Fig. 1.8.1. Later missions, such as boarding and temporarily operating an untended space station, may require monitoring, data collection, etc. via hard wire.

1.9.4 MOTV/EVA

There will be a tether interface between the crew capsule and an EVA man and perhaps an electrical power flying lead for hand tools.



DESIGN REF MISSION	ΔL(M)
S1, DR1	0
ER1	2
ER2	1
C3	1+6

NOTE: INDIVIDUAL LENGTHS COMPRISING ΔL CANNOT BE BROKEN DOWN FURTHER

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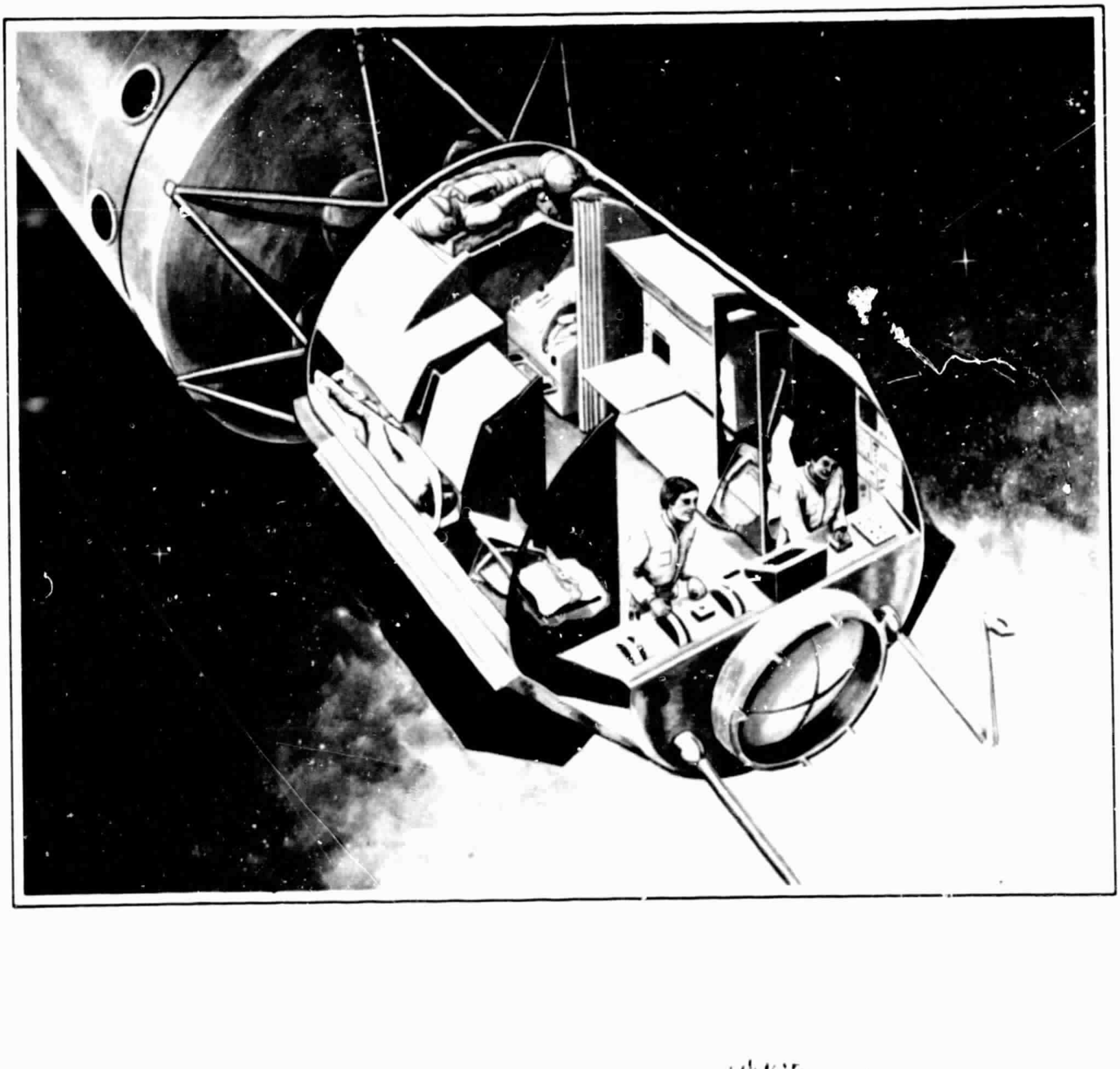
Fig. 1.9.4 MOTV Mission Equipments – STS Launch Requirements

1.9.5 MOTV/Mission Control Center (MCC)

Tracking and space vector update for the OTV/MOTV will be provided by TDRS or GPS in LEO. Introduction of the Space Sextant Autonomous Navigation System (or equivalent) on board the vehicle will relieve MCC entirely from a primary role in these functions. Similarly, MOTV will have autonomous monitoring of subsystems, fault isolation and switching to back up modes. This, again, will not require MCC in a primary role.

The function of MCC, located on the ground for this study, will be to:

- Continuously monitor the mission
- Recieve and store data
- Coordinate communication
- Advise and assist the crew in handling unexpected problems:
  - provide targeting data if MOTV navigation capability is lost
  - provide diagnostic expertise
  - suggest contingency workaround procedures



2 - GROWTH EVOLUTION

Although the primary concern of this document is to define a crew capsule to perform five Design Reference Missions, hence the two man baseline capsule, some consideration should be given to capsule growth. As discussed in Section 1.0, about twenty generic missions were identified at the beginning of the study (Fig. 1.1). Taking these missions as being typical of those that may evolve, crew number and type of support will change. Figure 2.1 illustrates how the crew capsule might evolve to accommodate various generic missions. Modularity is the key to simplifying these evolutionary changes.

The two-man baseline capsule lends itself to this concept of modular changes to satisfy changing requirements. The nose section and its internal layout of work stations is basically common for all missions. The cylindrical section shell with its EVA hatch and the rear dome are also common. For a three man capsule, a 1.5m length of cylinder is added to the shell, just aft of the nose section. Internal rearrangement is discussed in Subsection 2.1. This same three man capsule can now have an additional crew quarter added, as shown, to accommodate, say, a specialist for a particular mission; thus making a four-man capsule. The four-man capsule is used for the six-man, P4 mission to deep space. The remaining two men are accommodated in a storm shelter which provides emergency haven for the six crew in the event of an unpredicted solar flare occuring during the 15 days, one way, trip. The storm shelter mates to the EVA hatch provided in the capsule shell. P2 mission transports ten men to GEO. The trip is analogous to a one-day coach trip and calls for that type of facilities. Two of the men are pilot and co-pilot, leaving eight crew to be seated, as shown, in the center section of the capsule. This configuration is discussed more fully in subsection 2.2.

As other missions evolve, they may demand an airlock for multiple EVA operations or an MRWS as a positionable shirtsleeve work station. They can be mated to the capsule EVA hatch.

Apart from generic missions that demand a crew of three and, therefore, a three-man capsule, there is conviction in some quarters that a crew of three should be the minimum for any MOTV mission. One concern with the two man baseline is the acceptability of one man EVA with the other man minding the crew capsule or two men

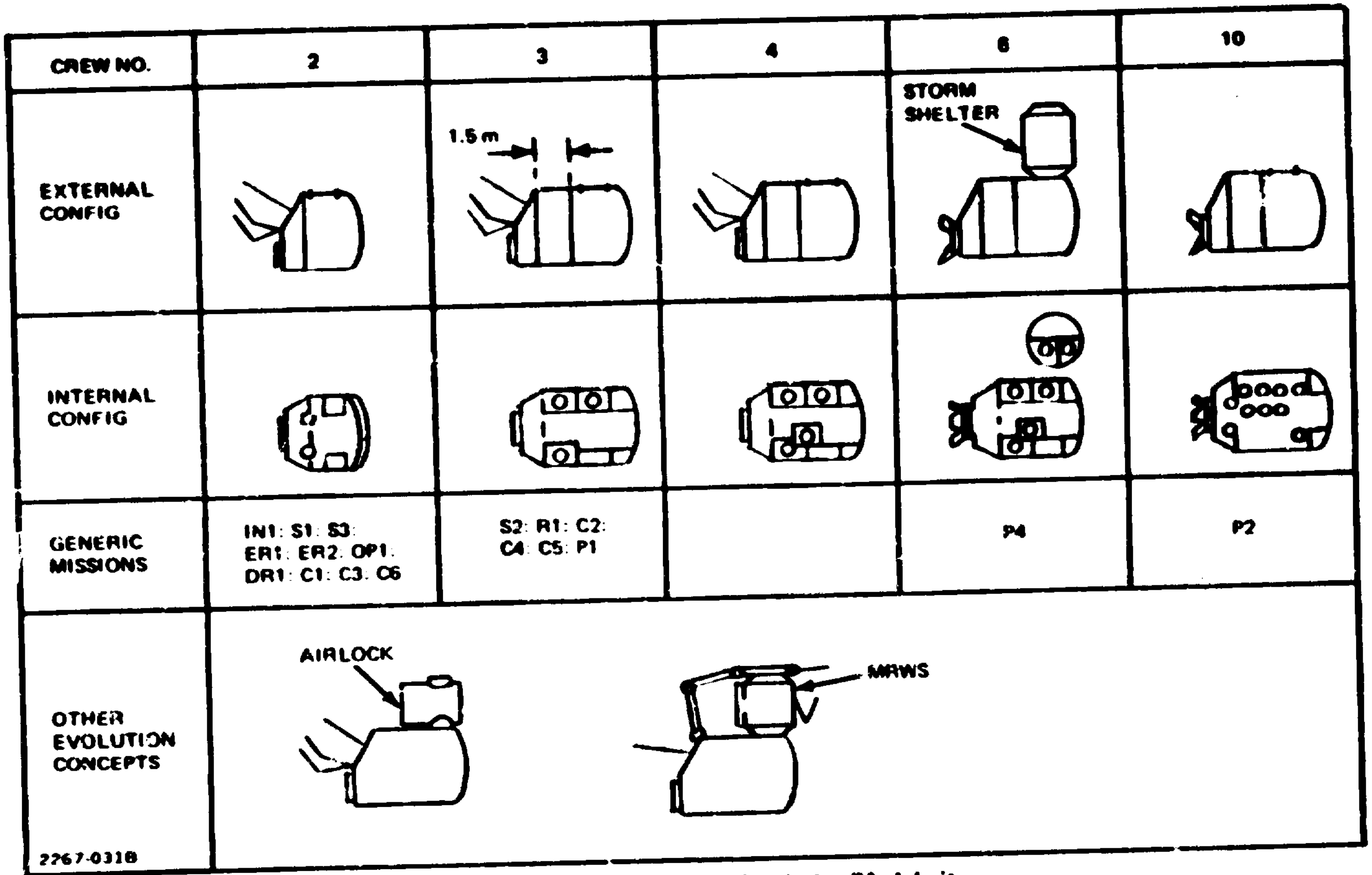


Fig. 2.1 Crew Capsule Growth/Evolution/Modularity

EVA with nobody in the capsule. This is discussed more fully in subsection 1.5.2. Some opinions are that even though two men are adequate for performing the DRMs tasks, the possibility of EVA, be it planned, contingency or emergency, should baseline a minimum crew of three...two men out, one man in the cabin.

In consequence of this, and the fact that three-man missions are proposed in the generic missions listing (Fig. 1.1) a three-man crew capsule is defined in our growth considerations (see subsection 2.1).

To further illustrate growth/evolution/modularity potential, subsection 2.2 takes a closer look at a 10-man crew transport capsule.

Another aspect of growth and evolution is that standards of crew comfort may change. The two-man baseline crew capsule is considered to be about the minimum volume that is functionally adequate for performing mission tasks. Opinion, flight experience, or increased crew activities may require a different length capsule to house the two-man crew. Figure 2.2 shows capsule shell weight and length sensitivity to changes in mission duration and free volume per man criteria as a function of crew comfort level. Crew comfort to be provided is subjective and two authorities are shown in the figure. They are Frazer Tolerance Level, Celantano Performance Level and thirdly, the level to which we have worked, Celentano Tolerance. The baseline crew capsule has $3.0M^3$ free volume per man and is good for 27 days at Celentano Tolerance Level.

The three-man capsule is the largest capsule investigated during the study. It is more generous in free volume per man since it was intended for long missions. Figure 2.3 shows sensitivities for the three-man capsule, whose length may be reduced to save weight or to optimize crew comfort for shorter duration missions. The three-man capsule presently provides $4.0M^3$ free volume per man.

2.1 THREE-MAN CREW CAPSULE

Groundrules for the main study required a minimum crew of three with each man having separate private quarters for rest and relaxation. This led to the crew capsule configuration shown in Fig. 2.1.1, the largest capsule studied. There are three main functional areas. The flight and mission stations are the same as the two-man baseline capsule, section 1.0. The center section provides crew quarters and equipment for their comfort while the aft compartment houses personal hygiene, waste management and EVA suit storage. Subsystems are stowed over the length of the capsule, under the floor and above the ceiling.

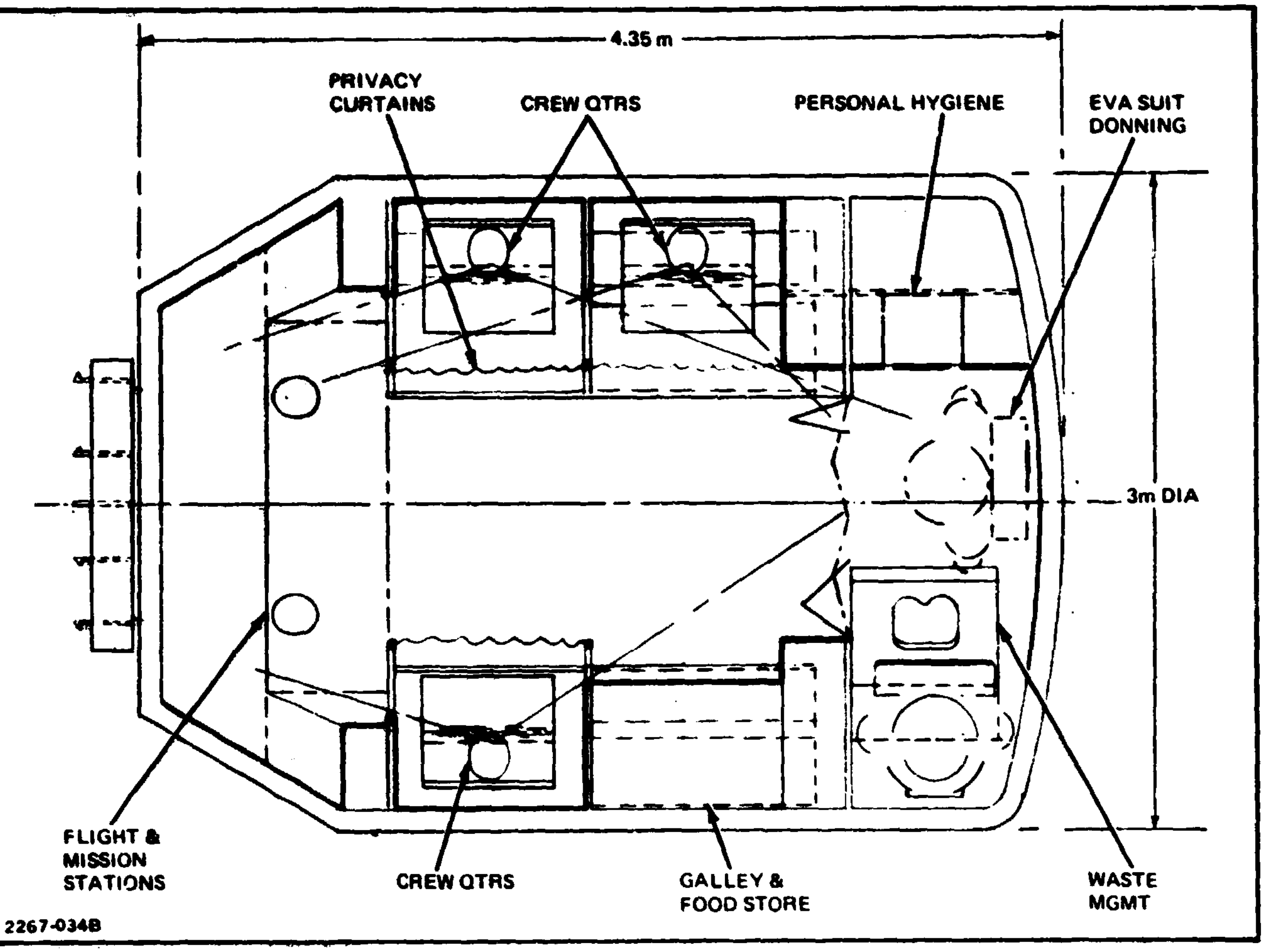


Fig. 2.1.1 Three-Man Crew Capsule Main Study Results

Being the same diameter as the two-man baseline capsule and having the same front end and rear dome, a 1.5m long cylindrical section can be added to the baseline capsule to provide the shell for this three-man capsule. Some rearrangement of facilities and the addition of crew quarters completes the reconfiguration.

Figure 2.1.2 gives a weight breakdown of this three-man crew capsule for mission S1. It shows a burn-out weight penalty of 979Kg compared to the two-man baseline capsule weight for S1, Fig. 1.3.1. Figure 2.1.3 shows the three-man crew capsule sensitivity.

CREW CAPSULE		WEIGHT, Kg
STRUCTURE		1,515
THERMAL PROTECTION		48
EPS		44
AVIONICS		149
ECLS		337
CREW ACCOMMODATION		768
PROPULSION CONTROLS		6
CONTINGENCY	(25%)	717
TOTAL DRY WEIGHT		3,584
CREW	(3)	245
CONSUMABLES	(19 DAYS)	343
BURN OUT WEIGHT		4,172

NOTES

- MANIPULATORS, ETC., CHARGED TO GEN PURPOSE MISSION EQUIP
- EPS SUBSYS IS POWER DISTR ONLY -- REMAINDER OF SUBSYS IN PROP CORE
- AVIONICS IS COMMAND/DISPLAY ONLY – REMAINDER OF SUBSYS IN PROP CORE

2267-035B

Fig. 2.1.2 Three-Man Crew Capsule Weight – Mission S1

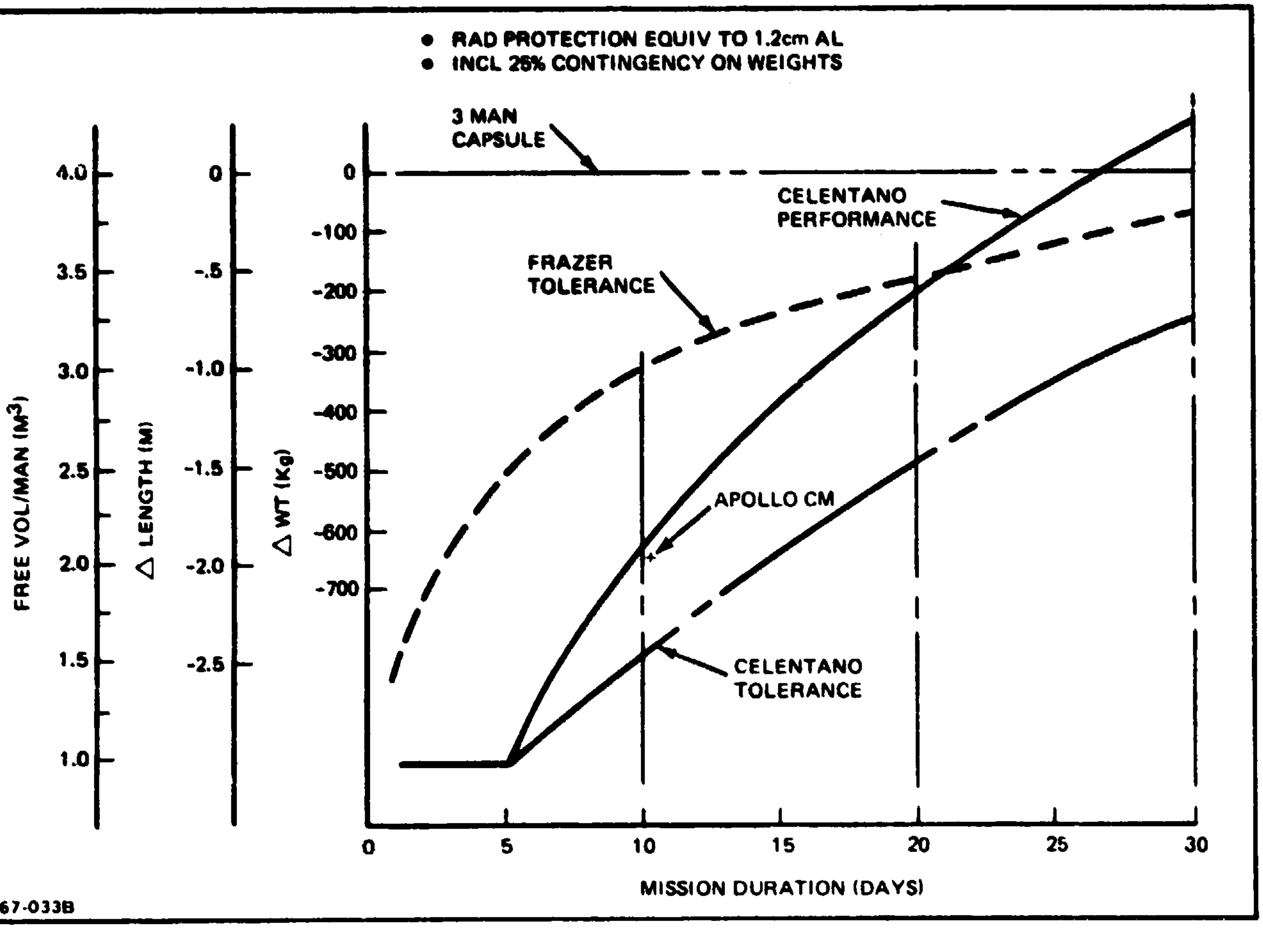


Fig. 2.1.3 Three-Man Crew Capsule Sensitivity – Structure Weight & Free Vol/Man vs Mission Duration

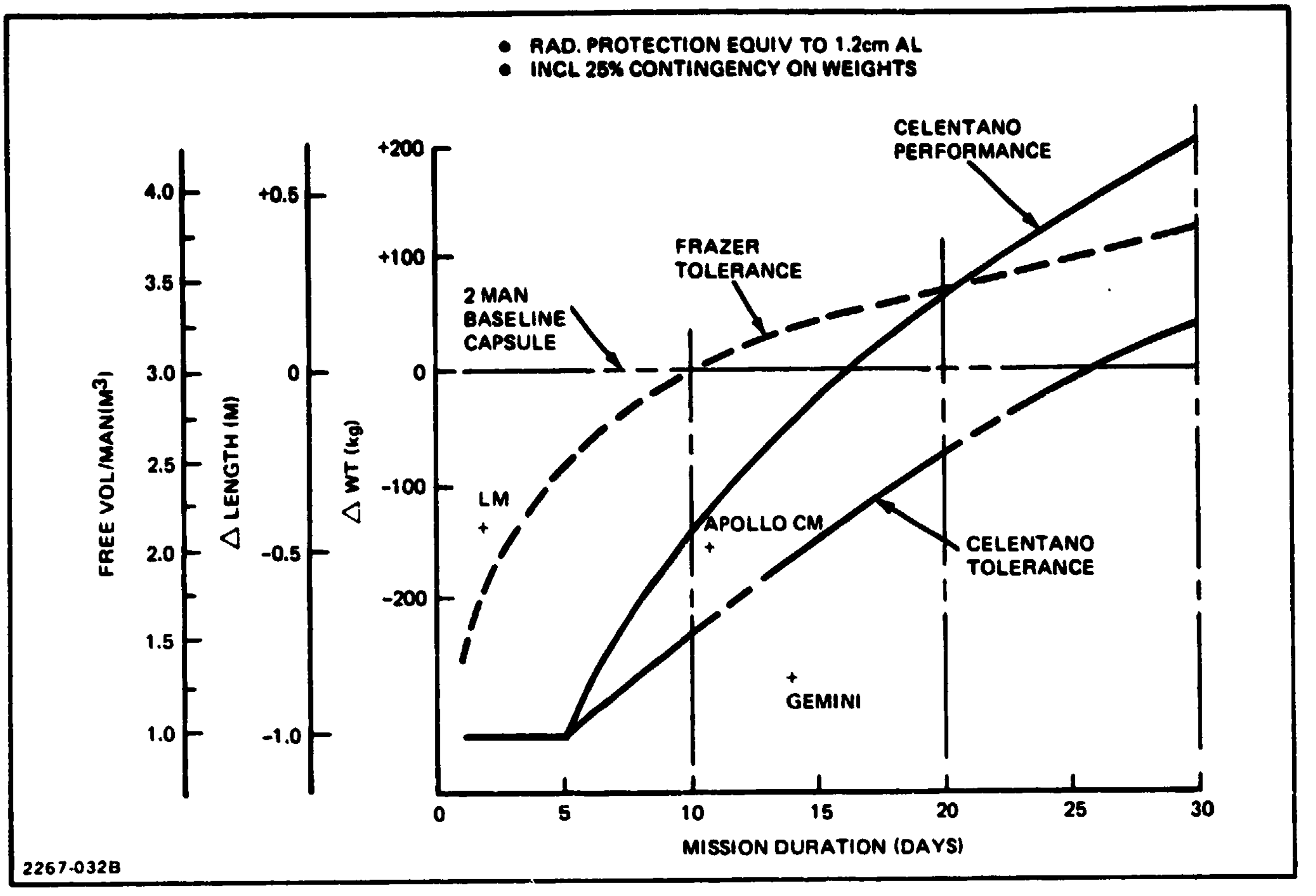


Fig. 2.2 Two-Man Crew Capsule Sensitivity — Structure Weight & Free Vol/Man vs Mission Duration

2.2 10-MAN PASSENGER TRANSPORT CAPSULE

Using the three-man growth capsule shell described in the preceding section, 10 men can be accommodated for a crew rotation mission to GEO. The people are only in the capsule for about a day and do not, therefore, require separate quarters or cooking facilities. The trip is analogous to a one-day coach ride and calls for that type of facilities. Layout of this capsule (Fig. 2.2.1) shows that internal modification to the three-man capsule retains the forward work station, which is occupied by two of the crew, and the aft station for personal hygiene, waste management, and EVA suit stowage/donning. The center section of the capsule is changed by removing crew quarters and the galley, then replacing them with four rows of two seats abreast. Thus, 10 crew are accommodated. Subsystems remain under the floor, but there is some relocation of those subsystems that were above the ceiling. A docking ring replaces the berthing ring.

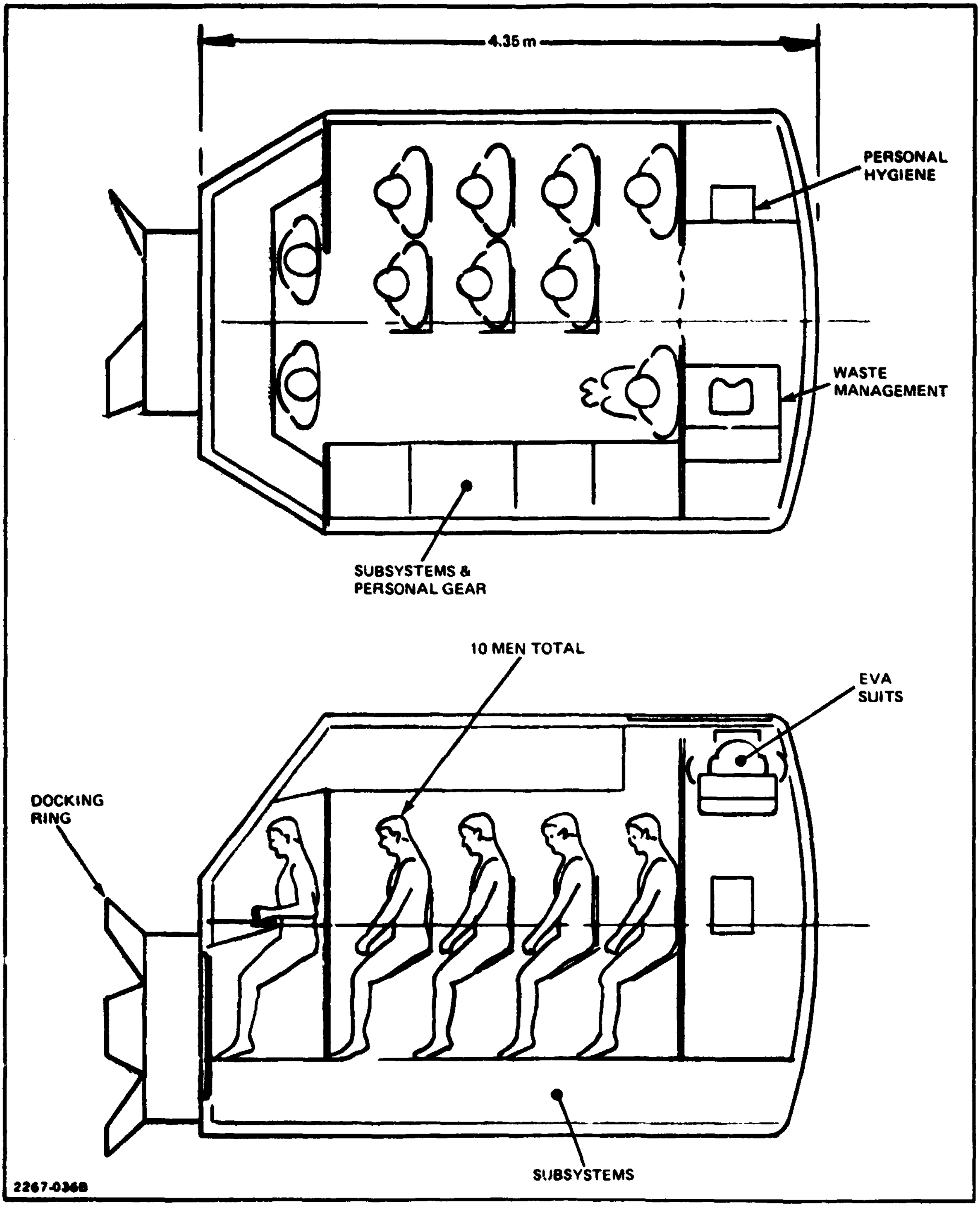


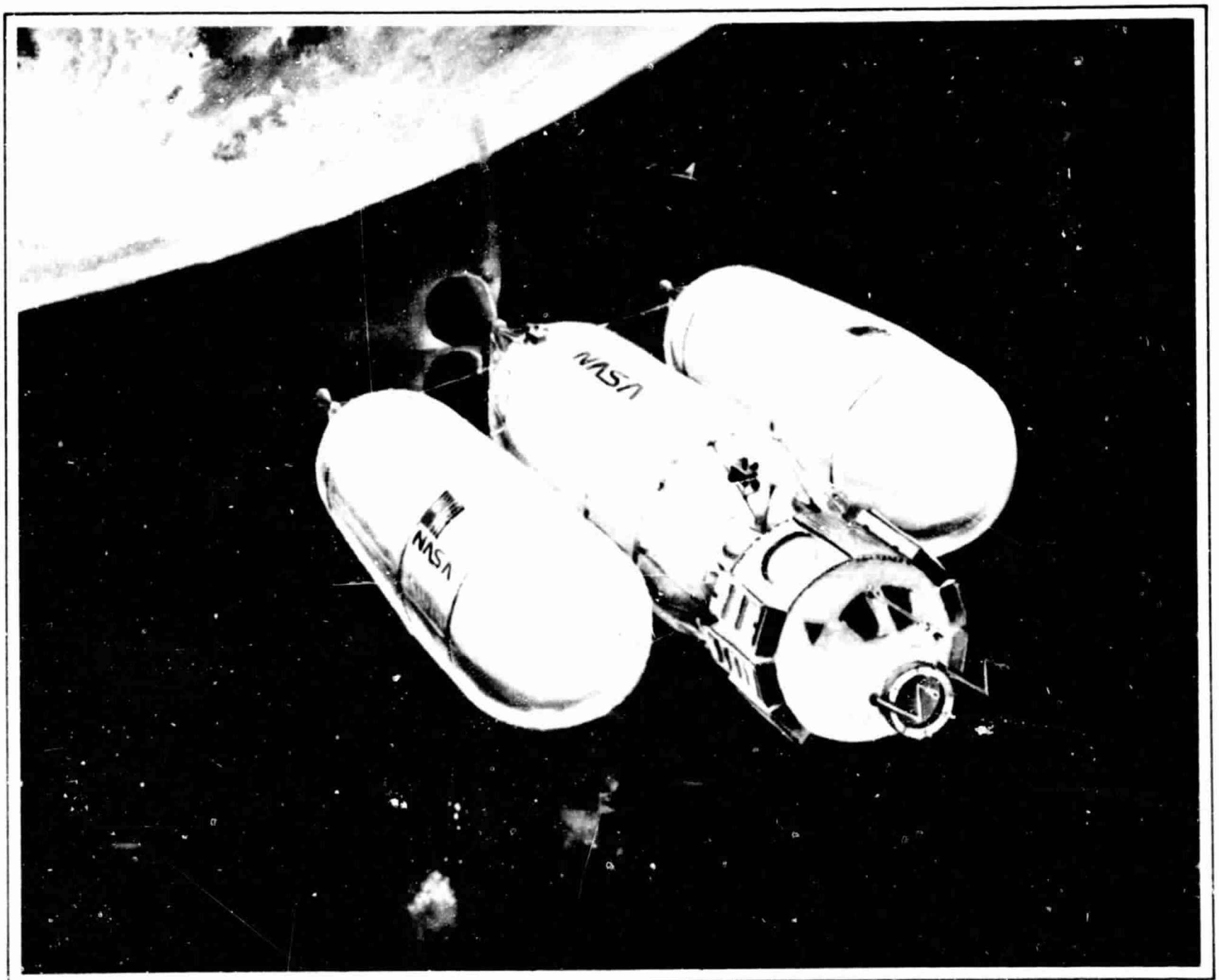
Fig. 2.2.1 10-Man Passenger Transport Crew Capsule – Mission P_2

Figure 2.2.2 gives a dry weight breakdown for this 10-man capsule and shows it to be only about 50 Kg heavier than the 3 man capsule dry weight. Crew quarters and galley weights for the three men have been exchanged for seats and additional ECLS equipment for 10 men.

	WT (Kg)
STRUCTURE	1,515
THERMAL PROTECTION	48
EPS	44
AVIONICS	149
ECLS	611
CREW ACCOM.	533
PROPULSION CONTROLS	6
CONTINGENCY (25%)	727
TOTAL DRY WEIGHT	3,633

2267-037B

Fig. 2.2.2 10-Man Passenger Transport Crew Capsule Weight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3 - POTENTIAL APPLICATIONS

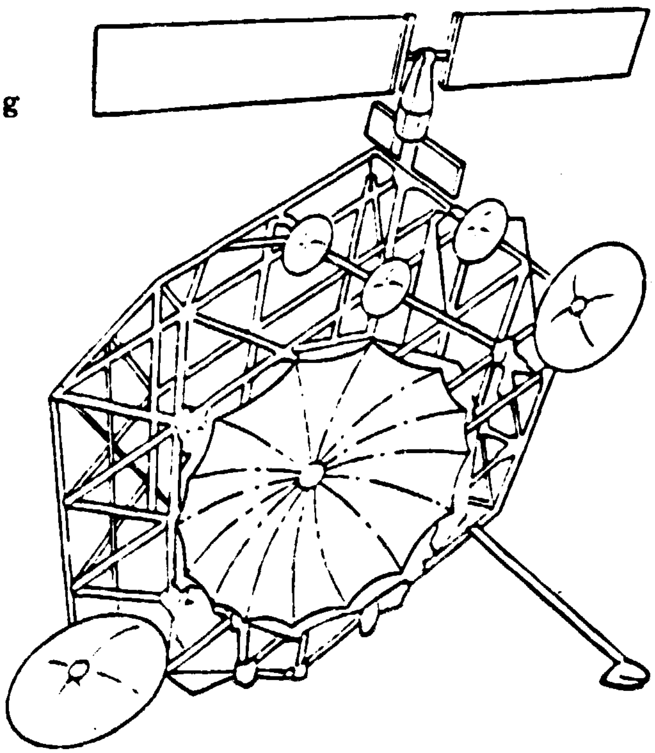
This section illustrates typical applications for the MOTV and it updates the Mission Handbook issued during the previous study. Five design reference missions are described. They cover a broad range of payload requirements, on-orbit mission tasks and mission durations. MOTV support of these missions is described in detail and illustrates the full functional and performance capabilities of the vehicle. Cost data for each mission is given, assuming ground turnaround of the vehicle, which has an all propulsive, 1 1/2 stage (drop tanks) propulsion module. A summary of mission equipment requirements for all generic missions is included in subsection 3.6.

1 DESIGN REFERENCE MISSION ER1 - EMERGENCY REPAIR OF A MULTIDISCIPLINED GEO PLATFORM

Mission Description: This mission is characterized by the unexpected nature of e failure incurred. It may be due to electronic component failure or mechanical ilure. In either case it is seriousness enough to warrent immediate repair. Further- ore, the total extent of the damage is not entirely known. The MOTV is deployed ith spare parts, repair tools, and on-board checkout equipment to determine the ll extent of the failure and fix it. In addition, standard servicing of the satellite ibsystems such as RCS fluid replenishment would also be done. The figure illu- rates the type of satellite needing repair.

Characteristics:

Weight	25,000 kg
Size	80 m
Power	40 kW
Orbit	GEO
Timeframe	1990
Life/Servicing Period . .	30/3 yr



2267-0758

Rationale for MOTV Use:

- Full nature of the failure cannot be determined remotely, and requires man onsite for repair and checkout
- Man's visibility and on-site decision making capability are not easily replaced by remote controlled, automated systems.

The following Figs. 3.1.1 through 3.1.9 reflect the design requirements and performance to achieve the ER1 mission. Similarly, subsection 3.2, 3.3, 3.4 and 3.5 are followed by supporting data.

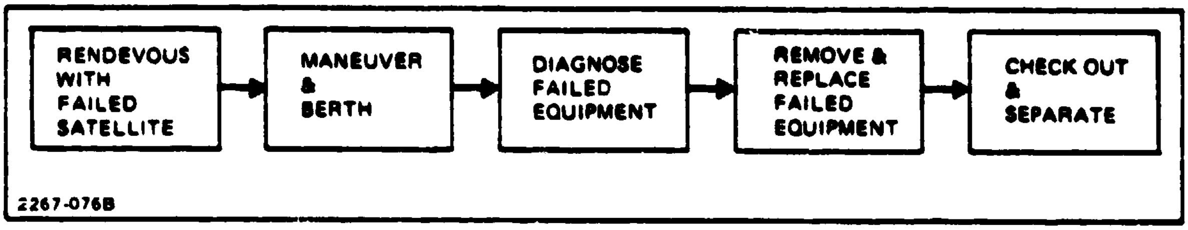


Fig. 3.1.1 ER1 – Emergency Repair (GEO)

ACTIVITY/FUNCTION	TIME HR:MIN	CREW MODE	NO. CREW	CREW TASK	REMARKS
• MANEUVER & BERTH	(1:00)	IVA			SPACE TUG DATA
– PREPARE FOR FINAL APPROACH – MANEUVER TO INSPECT SATELLITE	:45				
– MANEUVER TO BERTHING ATTITUDE	:06				
– ACTIVATE & POSITION BERTHING SYS – PERFORM CLOSING MANEUVER – CAPTURE SATELLITE & SECURE BERTHING	:10				
• DIAGNOSE FAILED EQUIPMENT	(2:45)	IVA			
– ACTIVATE MANIPULATOR SYS	:10				
– SHUTDOW ELECT. SYS AS NEEDED	:05				
– CHECK OUT SATELLITE SUBSYS	:30				
– DETAIL CHECKOUT & FAULT ISOLATION – SUPPORT SPACE-GRND SYS TEST AS NEEDED	2:00				
• REMOVE & REPLACE FAILED EQUIP.	(10:45)	IVA			
– REMOVE 30 m ANTENNA	:45				
o FOLD 30 m ANTENNA	–				
o REMOVE & STOW ANTENNA	–				
– REPAIR BEAM	:10				
o REMOVE & STOW BEAM SEGMENT	–				
c REPLACE & LOCK SEGMENT	–				
– REPLACE ANTENNA	1:05				
o MOUNT NEW ANTENNA	–				
o DEPLOY ANTENNA	–				
– SUPPORT SPACE-GROUND CHECKOUT	:20				
– SERVICE RCS UNITS (2)	3:00				
o REMOVE & STOW PROP. TANK	–				
o UNSTOW, INSTALL & C/O PROP. TANK	–				
– REBERTH	:45				
o STOW MANIPULATORS	–				
o RELEASE, MANEUVER & REBERTH	–				
o REPOSITION MANIPULATOR	–				
– REPAIR 10 m ANTENNA SYS	1:20				
o REMOVE & STOW COMPONENT	–				
o REPLACE COMPONENT	–				
– SUPPORT SPACE-GROUND C/O	:20				
– SERVICE RCS UNITS (2) (AS ABOVE)	3:00				
• SEPARATE & COMPLETE C/O	(1:00)	IVA			
SAFE & STOW MANIPULATOR	:15				
– SUPPORT SPACE GROUND C/O	:35				
– MANEUVER TO VERIFY SAT. CONF	:10				
TOTAL	15:30				

2267-077B

Fig. 3.1.2 ER1—Functions, Time and Tasks

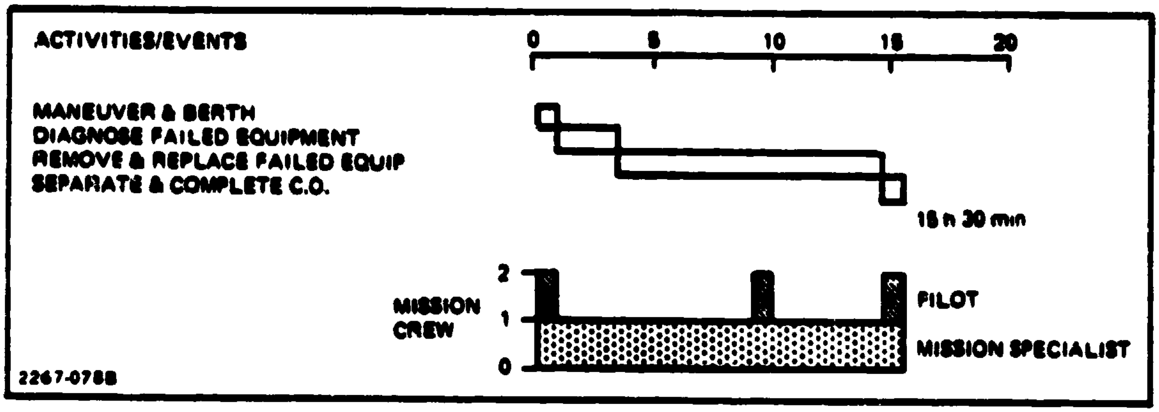


Fig. 3.1.3 ER1 – Timeline and Crew Requirements

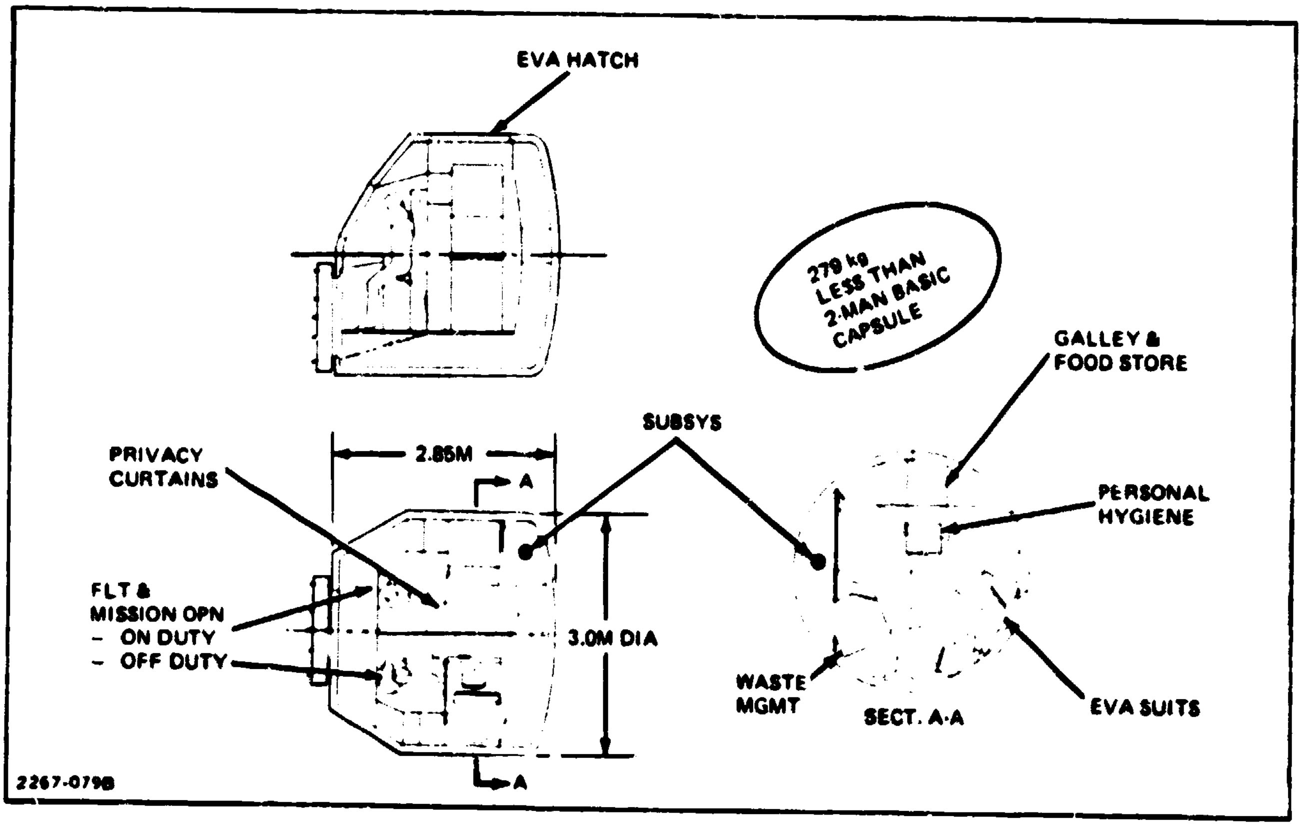


Fig. 3.1.4 Two-Man "Functional Minimum" Crew Capsule-Typical For All DRMs

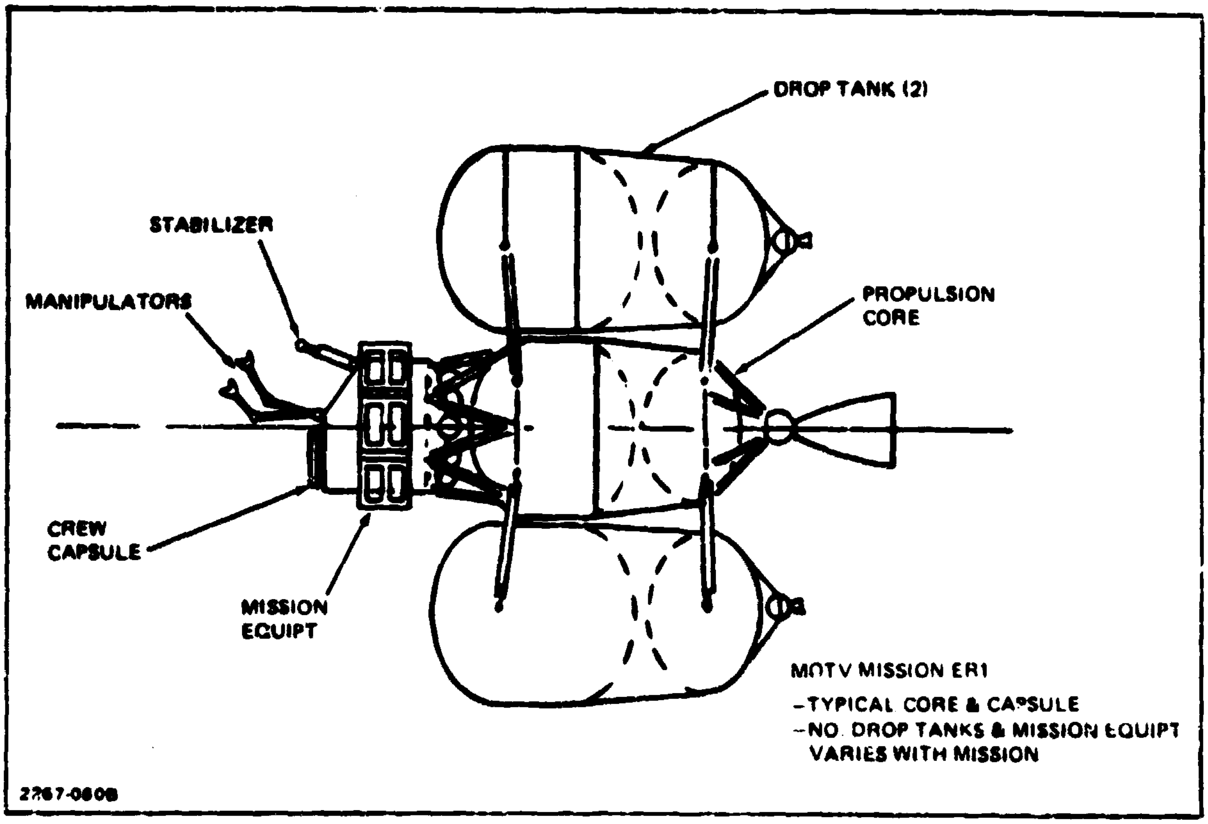


Fig. 3.1.5 MOTV Configuration for Mission ER1

	CREW CAPSULE	PROP'LS'N CORE	DROP TANKS (2)	MISSION EQUIP'T GENERAL PURPOSE	MISSION EQUIP'T DEDICATED
DRY WEIGHT	2775	3087	2950	631	408
CREW/CONSUMABLES	277	175			
RESERVES/RESIDS		298	470		
BURNOUT WEIGHT	3052	3558	3420	631	408
MAIN PROP – (CAPACITY)		(17,500)	(54,540)		
– LOADING		17,500	34,004		
ACPS PROP		675			
MISC		145			95
MOTV WEIGHT	3052	21,878	37,424	631	503
TOTAL MOTV WEIGHT	← 63,488 →				

2267-081B

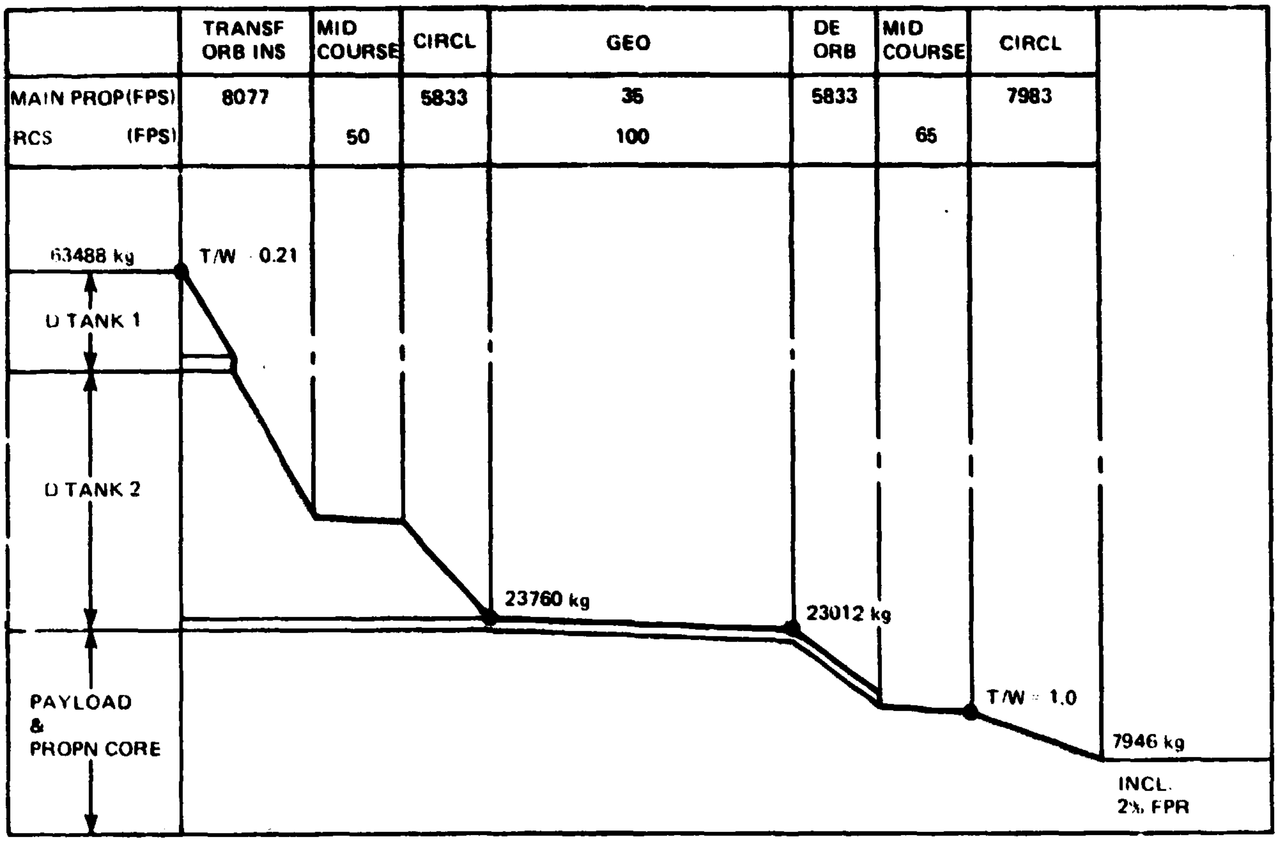
Fig. 3.1.6 ER1 Summary Weight Statement, kg

CREW CAPSULE		WEIGHT, kg
STRUCTURE		1113
THERMAL PROT		33
EPS		37
AVIONICS		125
ECLS		296
CREW ACCOM		610
PROPULSION		6
RECOVERY		–
CONTINGENCY	(25%)	555
TOTAL DRY WEIGHT		2775
CREW	(2)	163
CONSUMABLES	(3.4 DAYS)	114
BURNOUT WEIGHT		3052

NOTES
- MANIPULATORS, ETC., CHARGED TO GEN PURPOSE MISSION EQUIP.
- EPS SUBSYS IS POWER DISTR ONLY – REMAINDER OF SUBSYS IN PROP. CORE

2267-082B

Fig. 3.1.7 ER1 Weight Statement (Crew Capsule)



2267-083B

Fig. 3.1.8 Performance Data — Emergency Repair Mission (ER1)

	CREW CAPSULE	PROPULSION CORE	DROP TANKS (2)	TOTALS
MANAGEMENT				0.08
CREW PROVISIONS	0.01			0.01
TURNAROUND				2.20
FUEL		0.03	0.06	0.09
DROP TANKS			3.38	3.38
MISSION OPS				1.80
ORS SPARES	0.60	0.40		1.00
STS OPS				74.40
TOTAL				82.92

2267-084B

Fig. 3.1.9 Typical Cost per Mission ~ Mission ER1 (Constant '79 $ M)

3.2 DESIGN REFERENCE MISSION ER2 - EMERGENCY REPAIR OF A SURVEILLANCE SATELLITE IN A 12-HR/63° INCLINED ORBIT

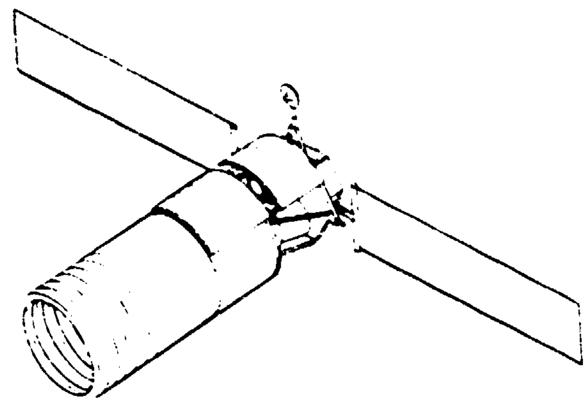
Mission Description: This mission is characterized in the same manner as Generic Mission ER1. In this case, however, the satellite and its orbit are very different. The satellite's electronics, optics or mechanical system may have failed. The MOTV is deployed to rendezvous and dock with the disabled satellite even assuming it has lost its stabilization and control system and is uncontrollably tumbling. The MOTV would stabilize the satellite and perform repairs as required. In addition, standard servicing of the satellite subsystem such as RCS fluid replenishment would also be done. The figure illustrates this mission.

Characteristics:

Weight	4100 kg
Size	NA
Power	4.5 kW
Orbit	12 hr/63°
Timeframe	1990s
Life/Servicing Period . .	20/3 yr

Rationale for MOTV Use:

- Same as Generic Mission ER1



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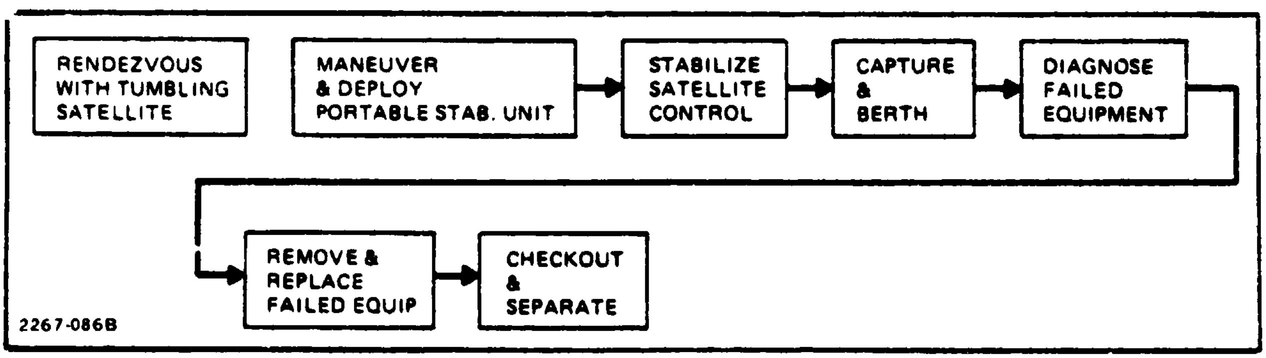

Fig. 3.2.1 ER2-Emergency Repair (HEO)

ACTIVITY/FUNCTION	TIME HR:MIN	CREW MODE	NO. CREW	CREW TASK	REMARKS
• MANEUVER & DEPLOY PSU	(1:00)	IVA			
– PREPARE FOR FINAL APPROACH	:40				
– MANEUVER TO INSPECT SATELLITE					
– MANEUVER TO PSU DEPLOYMENT ATTITUDE	:20				
– C/O, ACTIVATE & DEPLOY PSU					
• STABILIZE SATELLITE	(:30)	IVA			
– MANEUVER PSU TO SATELLITE	:10				
– MANEUVER PSU TO CAPTURE SATELLITE	:10				
– STABILIZE SAT. VIA PSU	:10				
• CAPTURE & BERTH	(:45)	IVA			
– MANEUVER TO INSPECT SATELLITE	:20				
– MANEUVER TO BERTHING ATTITUDE	:10				
– ACTIVATE & POSITION BERTH. SYS.	:05				
– PERFORM CLOSING MANEUVER	:10				
– CAPTURE & SECURE SAT. BERTH.					
• DIAGNOSE FAILED EQUIPMENT	(2:45)	IVA			
– ACTIVATE MANIPULATOR SYS	:10				
– SHUTDOWN ELECT. SYSTEM AS NEEDED	:5				
– CHECK OUT SATELLITE SUBSYS.	:30				
– DETAIL CHECKOUT & FAULT ISOLATION	2.00				
– SUPPORT SPACE-GRND SYS TEST AS NEEDED					
TOTAL	5:00				
• REMOVE & REPLACE FAILED EQUIPMENT	(6:40)	IVA			
– REMOVE & STOW SIGNAL PROCESSOR	:40				
– REPLACE SIGNAL PROCESSOR	:50				
– REMOVE & STOW PAYLOAD CONTROLLER	:30				
– REPLACE PAYLOAD CONTROLLER	:40				
– REPLENISH CYRO FLUID IN COOLER	:50				
– C/O COOLER	:10				
– SERVICE RCS UNITS (2)	3.00				
REMOVE & STOW RCS	–				
UNSTOW, INSTALL & C/O RCS	–				
• CHECK OUT & SEPARATE	(1:10)	IVA			
– SUPPORT SPACE-GROUND CHECKOUT	:35				
– REMOVE & STOW PSU	:10				
– SAFE & STOW MANIPULATORS	:15				
– MANEUVER TO VERIFY SAT. CONFIG	:10				
TOTAL	12:50				

2267-087B

Fig. 3.2.2 ER2--Functions, Time and Task

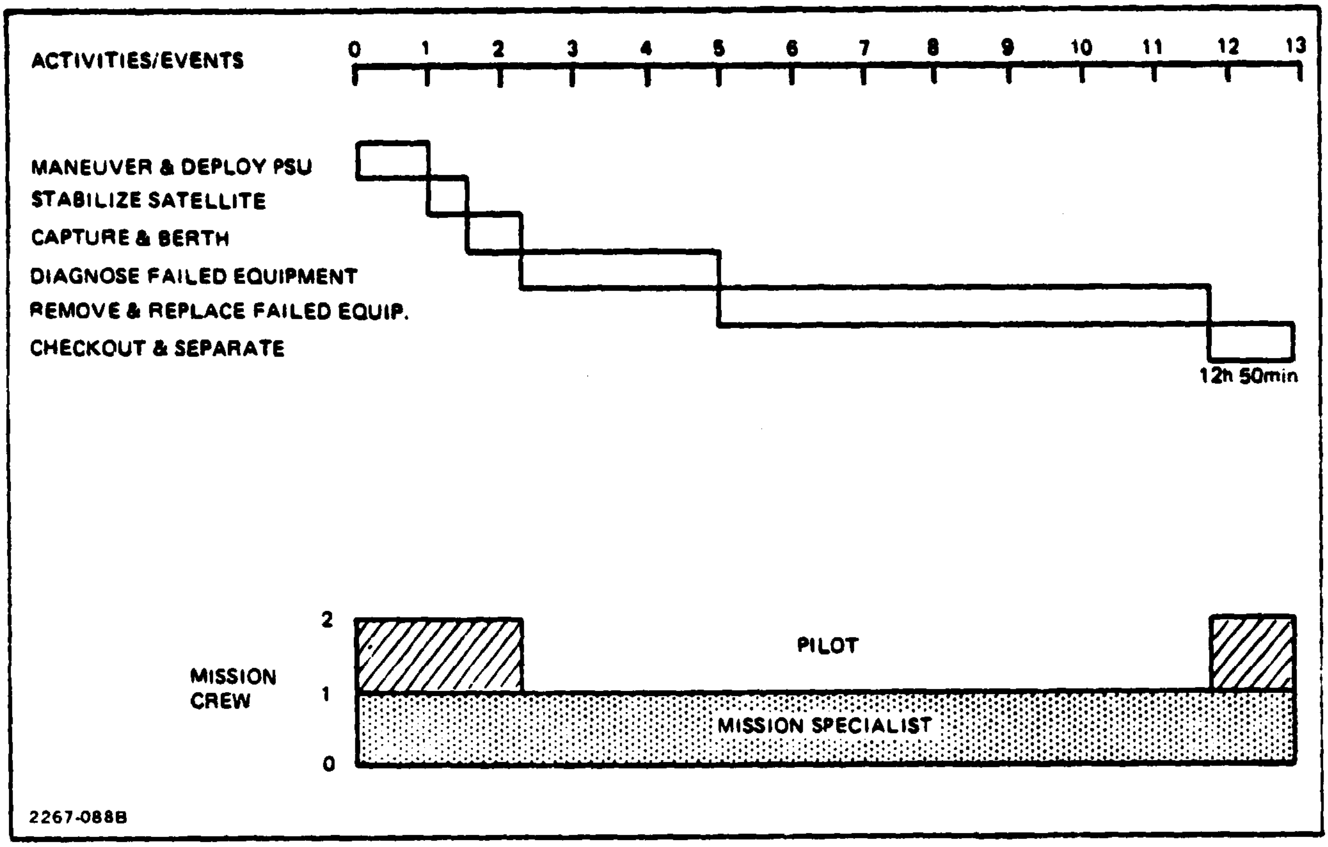

Fig. 3.2.3 ER2-Timeline and Crew Requirements

	CREW CAPSULE	PROP'LS'N CORE	DROP TANKS (1)	MISSION EQUIP'T GENERAL PURPOSE	MISSION EQUIP'T DEDICATED
DRY WEIGHT	2775	3087	1475	669	1012
CREW/CONSUMABLES	277	175			
RESERVES/RESIDS		296	235		
BURNOUT WEIGHT	3052	3558	1710	669	1012
MAIN PROP – (CAPACITY)		(17,500)	(27,270)		
– LOADING		17,500	7,840		
ACPS PROP		483			
MISC		145			77
MOTV WEIGHT	3052	21,686	9550	669	1089
TOTAL MOTV WEIGHT	36,046				

2267-089B

Fig. 3.2.4 ER2 Summary Weight Statement, kg

CREW CAPSULE		WEIGHT, kg
STRUCTURE		1113
THERMAL PROT		33
EPS		37
AVIONICS		125
ECLS		296
CREW ACCOM		610
PROPULSION		6
RECOVERY		
CONTINGENCY	(25%)	555
TOTAL DRY WEIGHT		2775
CREW	(2)	163
CONSUMABLES	(3.4 DAYS)	114
BURNOUT WEIGHT		3052

NOTES
- MANIPULATORS, ETC., CHARGED TO GEN PURPOSE MISSION EQUIP.
- EPS SUBSYS IS POWER DISTR ONLY – REMAINDER OF SUBSYS IN PROP. CORE

2267-090B

Fig. 3.2.5 ER2 Weight Statement (Crew Capsule)

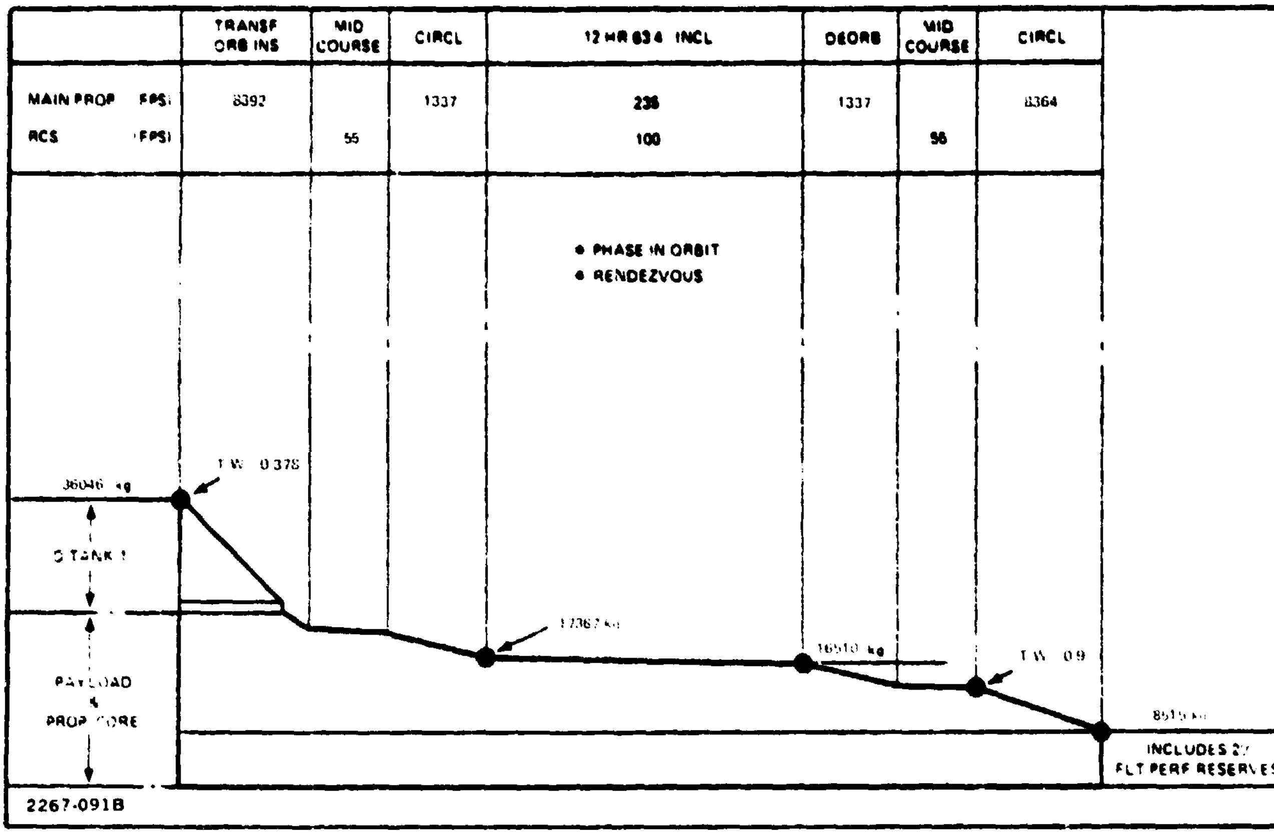

Fig. 3.2.6 Performance Data – Emergency Repair Mission (ER2)

	CREW CAPSULE	PROPULSION CORE	DROP TANKS (1)	TOTALS
MANAGEMENT				0.06
CREW PROVISIONS	0.01			0.01
TURNAROUND			–	2.20
FUEL		0.03	0.01	0.04
DROP TANKS			1.69	1.69
MISSION OPS				1.44
OPS SPARES	0.60	0.40		1.00
STS OPS				50.40
TOTAL				56.84

2267-092B

Fig. 3.2.7 Typical Cost per Mission – Mission ER2 (Constant '79 $ M)

3.3 DESIGN REFERENCE MISSION DR1 - DEBRIS REMOVAL FROM EGO

Mission Description: The MOTV is dispatched to GEO to sweep debris from a 45° sector of the orbit. Three stops are made in orbit; the first two to pick up dead but stable communications satellites (Intelsat type) each separated 22 1/2° in longitude, and the third to remove spent propellants tanks, propulsion stages, etc., which are orbiting in GEO. After collecting each of these payloads the MOTV propels them to a high orbit junkyard where their presence would not interfere with future space endeavors. The orbit of this junkyard is 2000 n mi above GEO. After depositing its payload the MOTV deorbits and returns to earth. The figure illustrates this mission scenario.

Characteristics:

Weight	5500 kg
Size	NA
Power	NA
Orbit.	GEO
Timeframe	1990s
Life/Servicing Period .	NA

Rationale for MOTV Use:

- The MOTV may perform this mission as part of a servicing or repair mission, or independently depending on the number and physical characteristics of the satellites being transferred
- This mission is much more complex if attempted unmanned and is beyond the performance capabilities of future teleoperator systems or cargo OTVs.

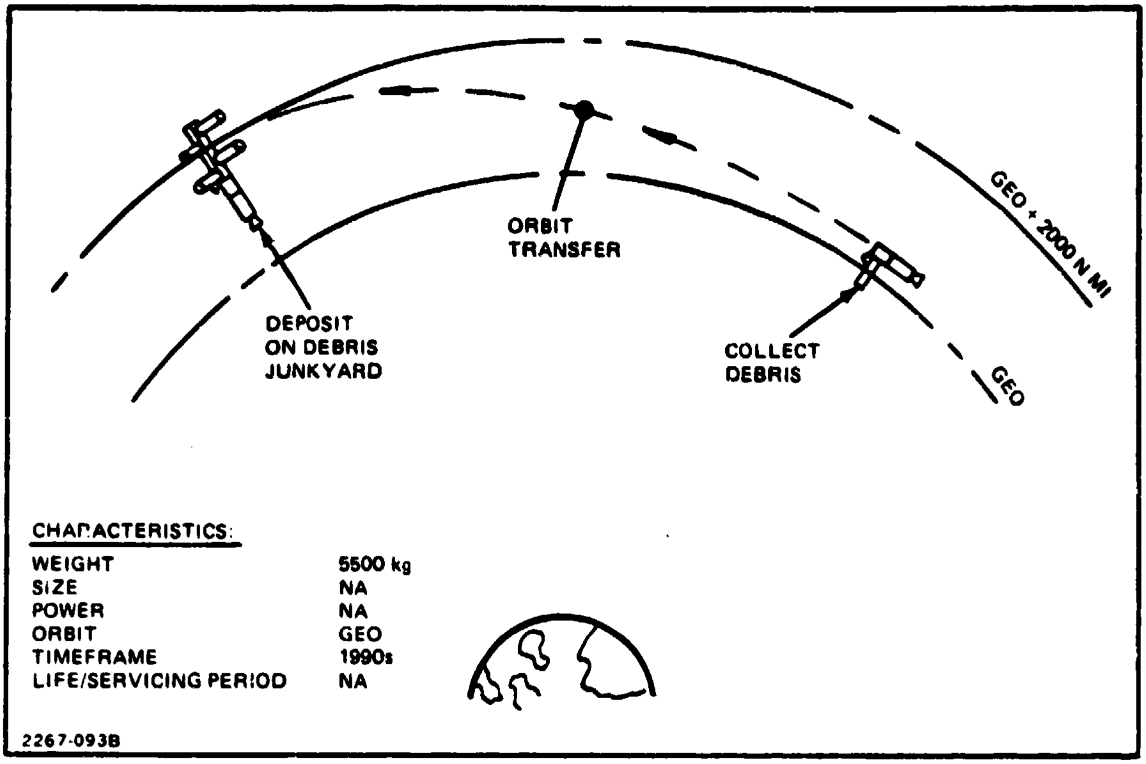

Fig. 3.3.1 Mission DR1 Debris Removal From GEO

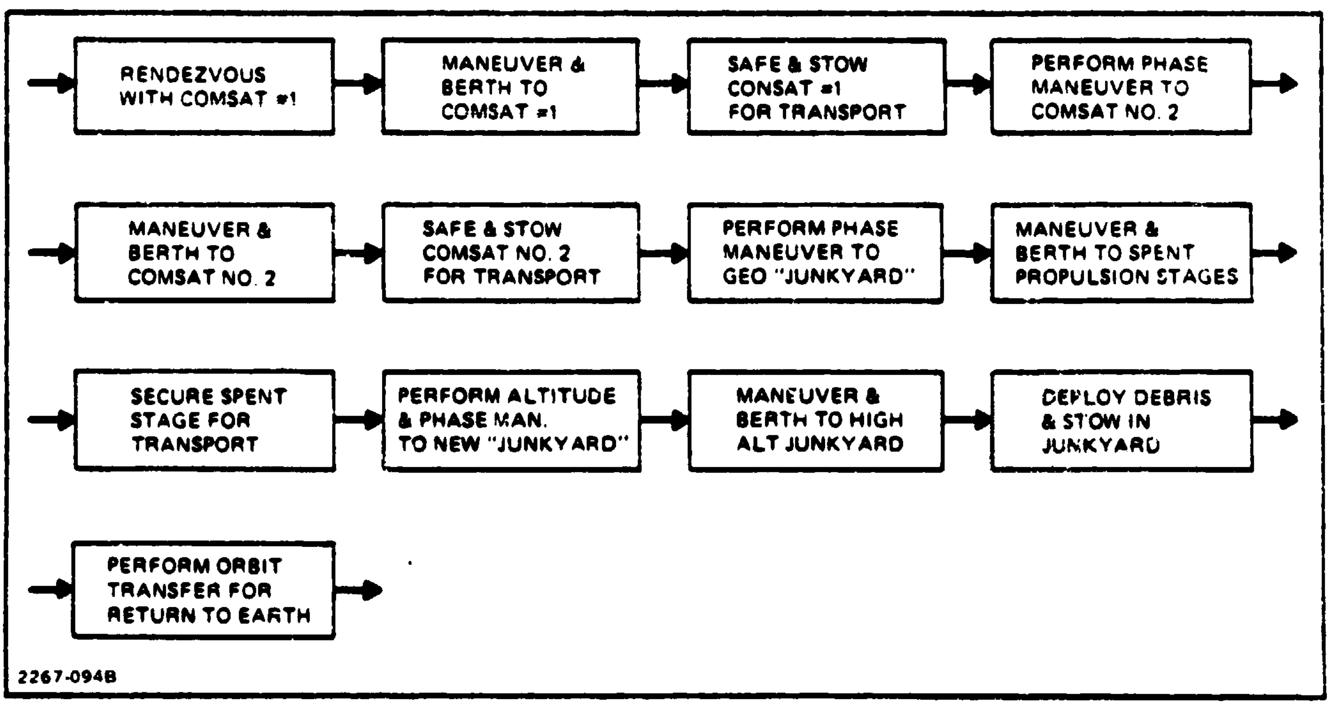

Fig. 3.3.2 DR1 – Debris Removal From GEO

ACTIVITY/FUNCTION	TIME HR: MIN	CREW MODE	NO. CREW	CREW TASK	REMARKS
• MANEUVER & BERTH TO COMSAT NO. 1	(1:20)	IVA		NAV & GUIDANCE OF MOTV TO BERTH WITH STABLE SAT.	
– PREPARE FOR FINAL APPROACH	40				
– INSPECT SATELLITE	:20				
– MANEUVER TO BERTHING ATTITUDE	: 5				
– ACTIVATE & POSITION BERTHING SYSTEM	: 5				
– PERFORM CLOSING MANEUVER & BERTH	:10				
• SAFE & STOW COMSAT NO. 1 FOR TRANSPORT	(1:45)	IVA		OPERATE MANIPULATORS	
– SHUTDOWN SAT. POWER SUPPLY	:30				
– VENT PROPELLANTS/FLUIDS AS NEEDED	:20				
– REMOVE, SAFE & STOW APPENDAGES	:25				
– STOW SATELLITE	:30				
• PERFORM 22½° PHASING MANEUVER TO COMSAT NO. 2	(48:00)	IVA		NAV & GUIDANCE	
• REPEAT STEPS 1 & 2 FOR COMSAT NO. 2	(3:05)	IVA		OPERATE MANIPULATORS	
• PERFORM 22½° PHASING MANEUVER TO GEO JUNKYARD	(48:00)	IVA		NAV & GUIDANCE	
• REPEAT STEPS 1 & 2 TO RETRIEVE SPENT PROPULSION STAGE	(3:05)	IVA		OPERATE MANIPULATORS	
• PERFORM ALTITUDE & PHASING MANEUVER TO HIGH ALTITUDE JUNKYARD	(24:00)	IVA		NAV & GUIDANCE	
• MANEUVER & BERTH TO JUNKYARD	(1:20)	IVA		NAV & GUIDANCE	
• DEPLOY DEBRIS & STOW IN JUNKYARD	(1:00)	IVA		MANIPULATOR OPERATIONS	
TOTAL	131:35				

2267-095B

Fig. 3.3.3 DR1-Functions, Time, and Tasks

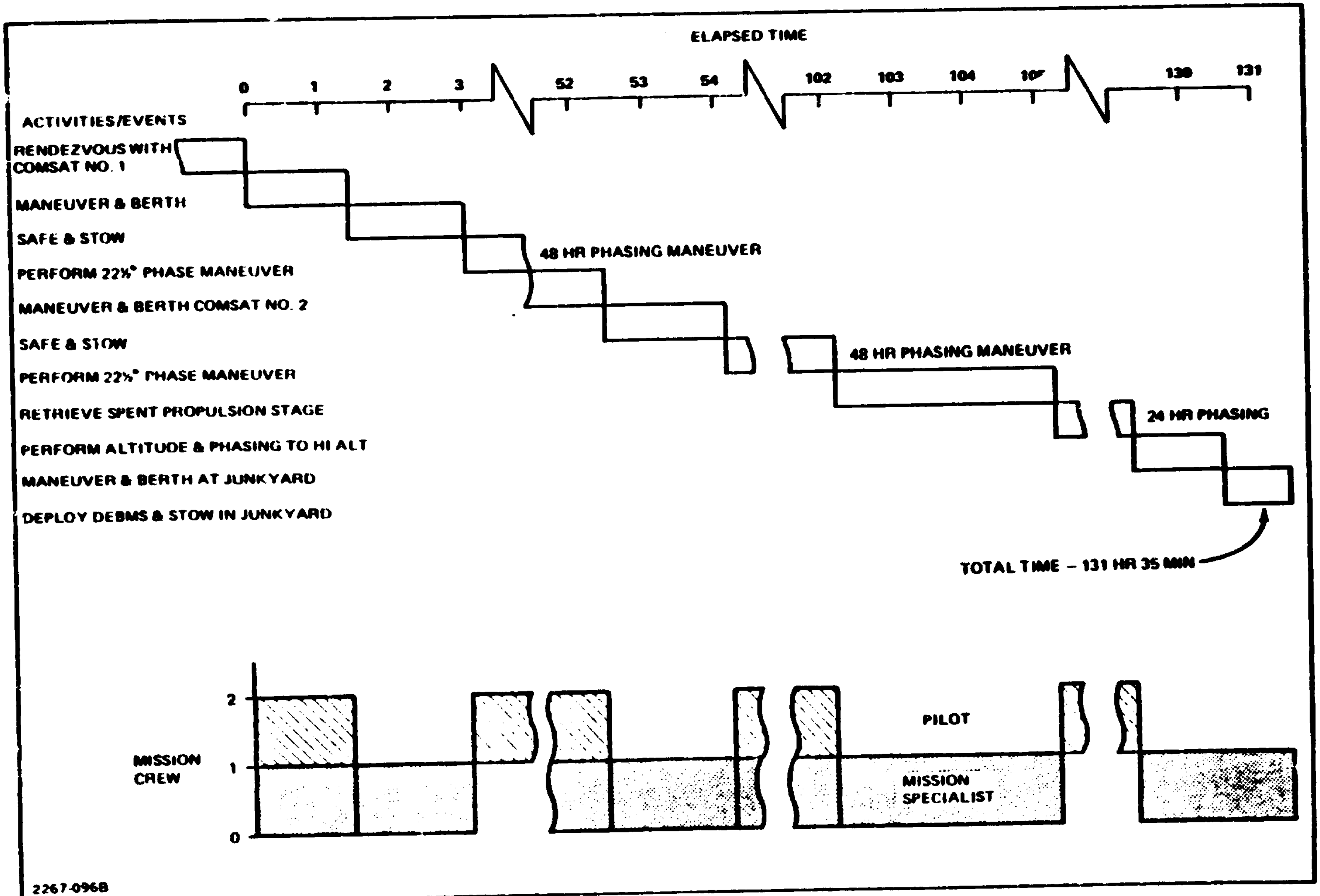

Fig. 3.3.4 DR1-Timeline and Crew Requirements

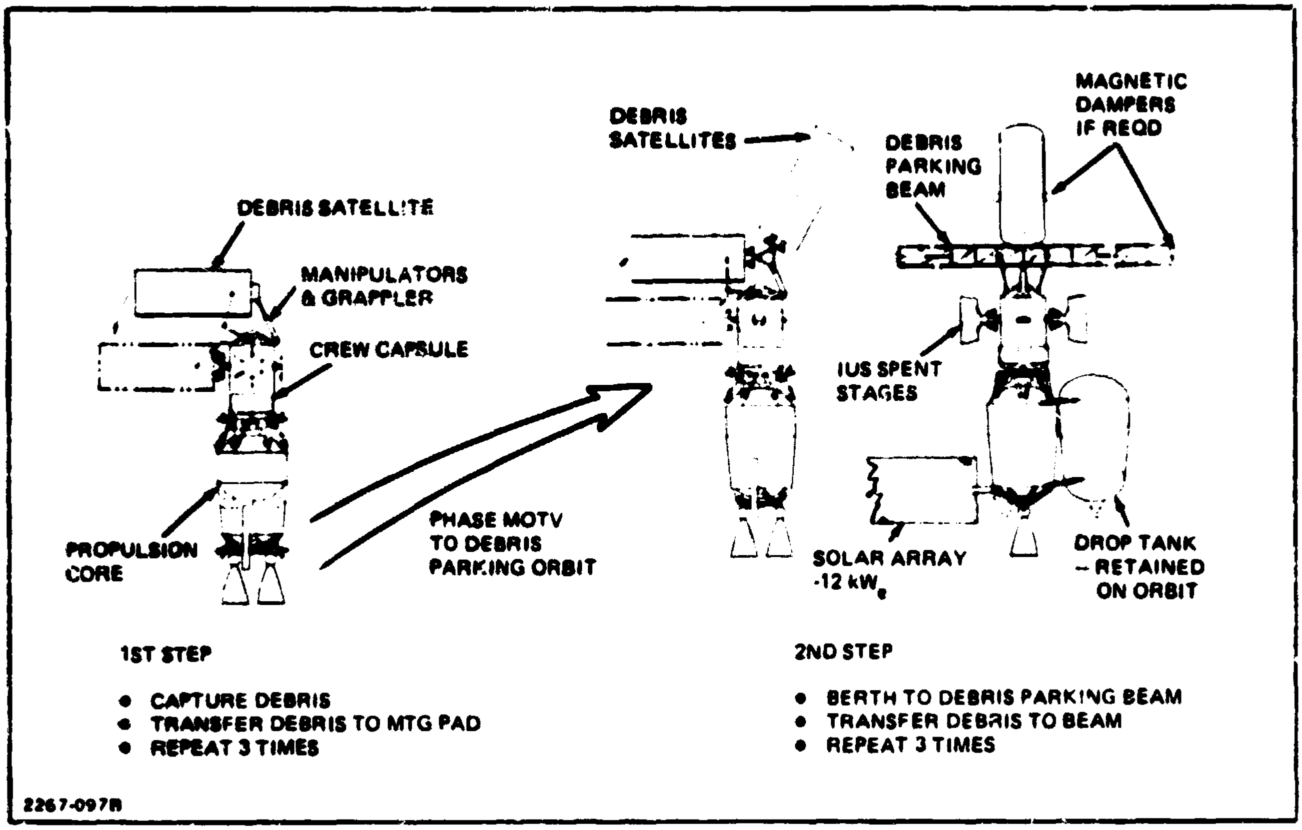

Fig. 3.3.5 Scenario for Mission DR1

	CREW CAPSULE	PROP'LS'N CORE	DROP TANKS (2)	MISSION EQUIP'T GENERAL PURPOSE	MISSION EQUIP'T DEDICATED
DRY WEIGHT	2776	3087	2950	824	–
CREW/CONSUMABLES	324	323			
RESERVES/RESIDS		296	470		
BURNOUT WEIGHT	3099	3706	3420	824	–
MAIN PROP – (CAPACITY)		(17,500)	(54,540)		
– LOADING		17 500	40,708		
ACPS PROP		1,652			
MISC		145			
MOTV WEIGHT	3099	23,003	44,128	824	–
TOTAL MOTV WEIGHT	71054				

2267-098B

Fig. 3.3.6 DR1 Summary Weight Statement, kg

CREW CAPSULE		WEIGHT, kg
STRUCTURE		1113
THERMAL PROT		33
EPS		37
AVIONICS		125
ECLS		296
CREW ACCOM		610
PROPULSION		6
RECOVERY		-
CONTINGENCY	(25%)	555
TOTAL DRY WEIGHT		2775
CREW	(2)	163
CONSUMABLES	(9.3 DAYS)	161
BURNOUT WEIGHT		3099

NOTES
- MANIPULATORS, ETC., CHARGED TO GEN PURPOSE MISSION EQUIP.
- EPS SUBSYS IS POWER DISTR ONLY – REMAINDER OF SUBSYS IN PROP. CORE

2267-099B

Fig. 3.3.7 DR1 Weight Statement (Crew Capsule)

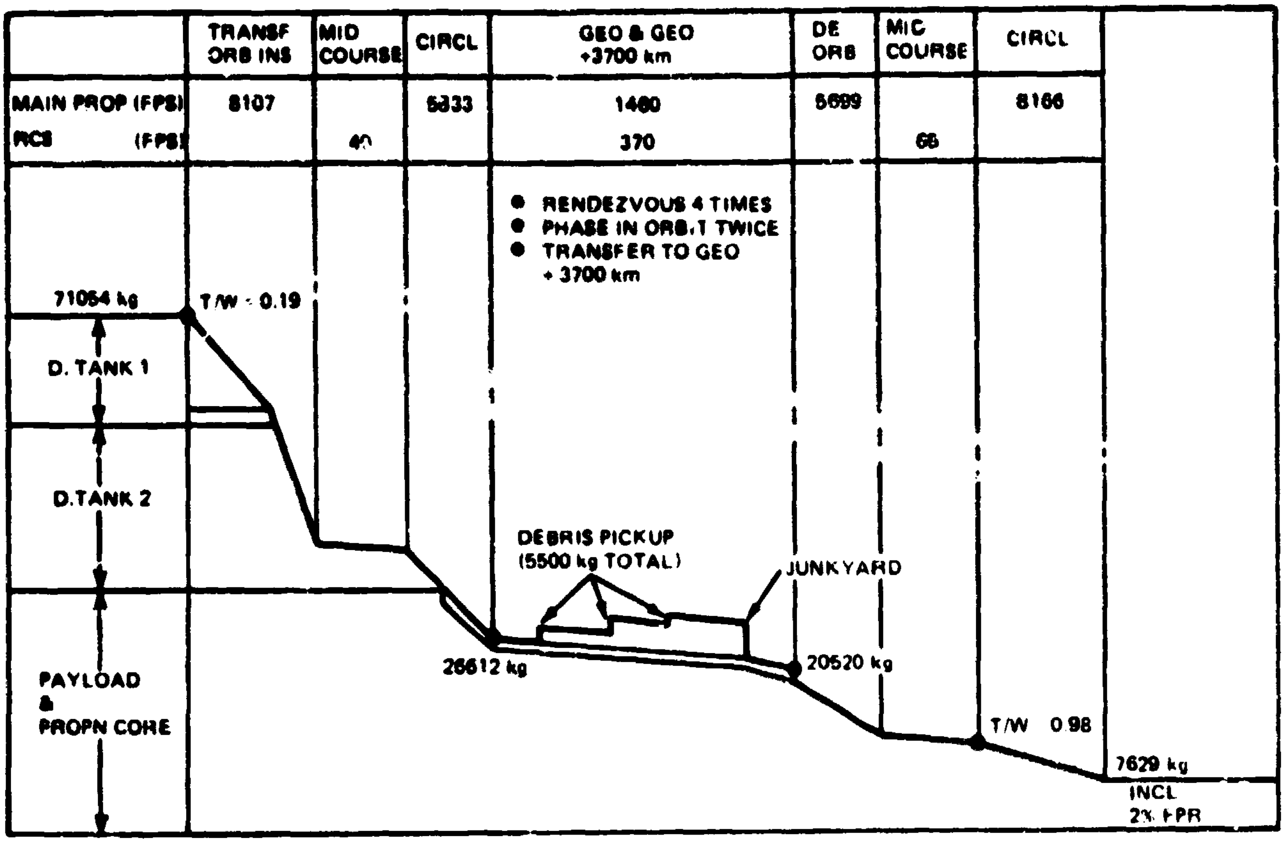

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Fig. 3.3.8 Performance Data — Debris Removal Mission (DR1)

	CREW CAPSULE	PROPULSION CORE	DROP TANKS (3)	TOTALS
MANAGEMENT				0.08
CREW PROVISIONS	0.02			0.02
TURNAROUND				2.20
FUEL		0.03	0.07	0.10
DROP TANKS			3.38	3.38
MISSION OPS				1.32
OPS SPARES	0.60	0.40		1.00
STS OPS				77.9
TOTAL				86.0

2267-104B

Fig. 3.3.9 Typical Cost per Mission — Mission DR1 (Constant '79 $ M)

3.4 DESIGN REFERENCE MISSION S1 - SERVICING OF FOUR COMMUNICATIONS SATELLITES USING MMS MODULES

Mission Description: Four communications satellites, all using standard Multimission Module Spacecraft (MMS) type hardware for subsystem support functions and all identical to each other, are serviced by the MOTV. The satellites are all located in GEO, 90° apart. Periodically, the MOTV visits each of these satellites and services the MMS type subsystems as depicted in the figure below. Modular replacement of each of the MMS subsystems is done on an "as required" basis. After servicing and checkout of each satellite the MOTV returns to earth with the used MMS modules, jettisoning them with the last propellant drop tank just before rendezvous with the STS in earth orbit.

Characteristics:

Weight . . . . 421 kg per Sat.

Size
- Length . . . . 1.2 m
- Width. . . . . 1.2 m
- Height . . . . 0.46 m

Power . . . . 1.2 kW Avg

Orbit . . . . GEO

Timeframe. . . . . Late 80s

Life/Serviced Period . . 20/2 Yr

Rationale for MOTV Use:

- Servicing satellites remotely using teleoperators operated from earth is more complex, less versatile, and less reliable than having man "on site" to perform this function
- Servicing and checkout is more thorough with man on-site, and contingencies can be more readily handled.

C-2

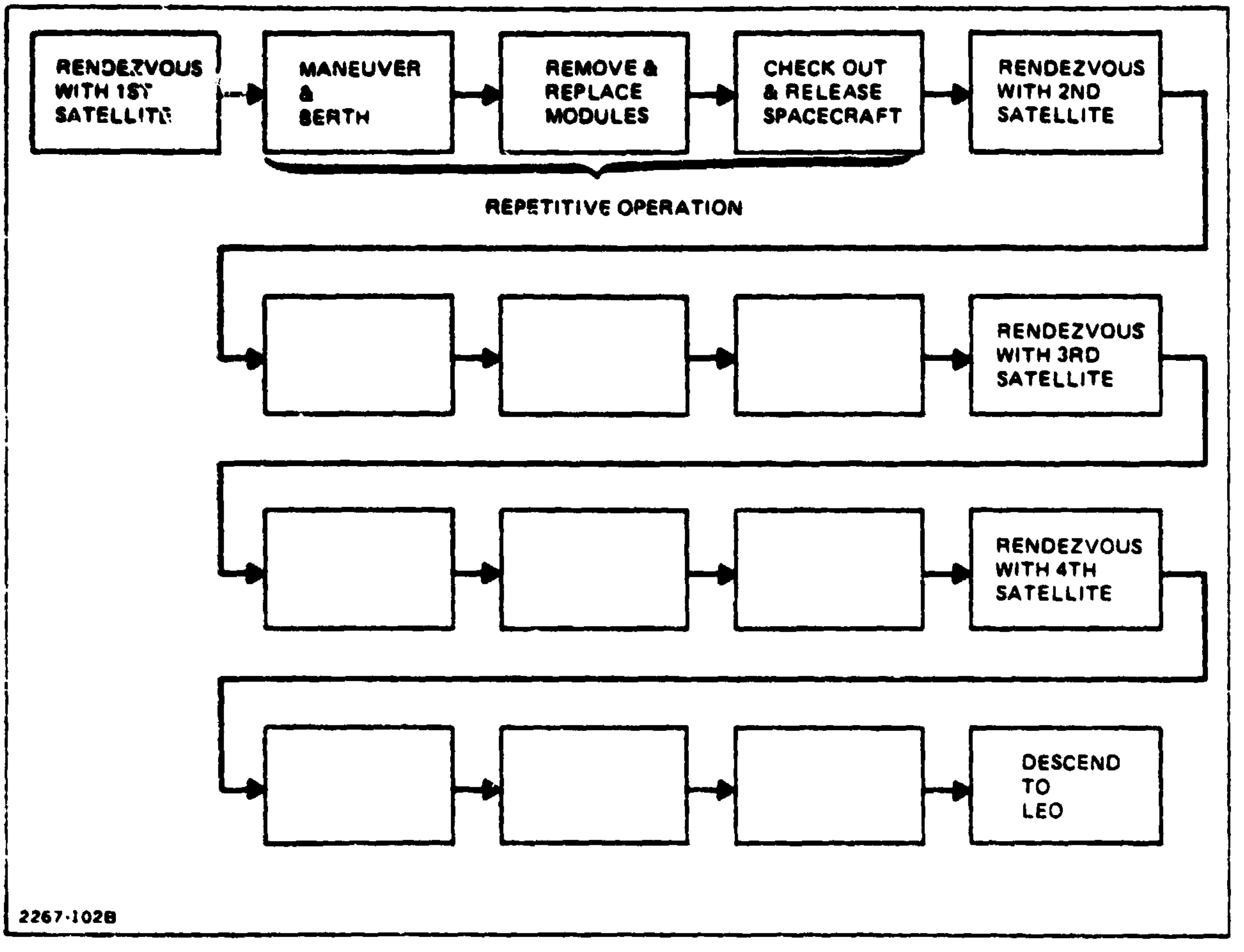


Fig. 3.4.1 S1-Modular Level Servicing (4 GEO Satellites – 90° Apart)

ACTIVITY/FUNCTION	TIME HR. MIN	CREW MODE	NO. CREW	CREW TASK	REMARKS
• MANEUVER & BERTH WITH SATELLITE 1	(1:00)	IVA			
– PREPARE FOR FINAL APPROACH				ALIGN G & N ACTIVATE TV	
– MANEUVER TO INSPECT SATELLITE	:45			ACQUIRE & TRACK TARGET	
– MANEUVER TO BERTHING ATTITUDE				VERIFY STABILITY, OPERATE	
– ACTIVATE & POSITION BERTHING SYSTEM	:05			C & DS – SAFE ?	
– PERFORM CLOSING MANEUVER	:10			SATELLITE SYSTEM	
– CAPTURE & SECURE SATELLITE BERTHING					
• REMOVE & REPLACE MODULES	(3:35)	IVA			
– ACTIVATE & POSITION MANIPULATORS (2)	:10				
– UNSTOW MMS MODULE & MOVE TO SATELLITE	:20				
– ENGAGE MODULE HOLDER ON SATELLITE	:05				
– REMOVE MMS MODULE & SWING TO SIDE	:10				
– SWING REPLACEMENT MODULE IN POSITION & ENGAGE	:05				
– RESTOW & SECURE USED MODULE	:20				
– ROTATE SAT. FOR MODULE SERVICING	:10				
– REMOVE & REPLACE 2 OTHER MODULES	2:00				1:00 EA.
– SAFE/STOW MANIPULATORS	:15				
• CHECK OUT & RELEASE SPACECRAFT	(1:10)	IVA			
– CHECK OUT SATELLITE SYS	:15				
– RELEASE BERTHING DEVICE					
– SAFE/STOW BERTHING DEVICE	:20				
– MANEUVER TO VERIFY SATELLITE CONFIG					
– SUPPORT SATELLITE SPACE–GROUP C/O	:35				
• RENDEZVOUS TO SATELLITE NO. 2	(114:00)	IVA			4¾ DAYS
– PHASING ORBIT INSERTION					90° SEPARATION
– APOGEE ADJUST & COAST					
– PHASE ADJUST & COAST	114:00				
– CIRCULARIZATION					
– TERMINAL PHASE BRAKING					
• MANEUVER & BERTH TO SATELLITE NO. 2	1:00	IVA			
• REMOVE & REPLACE MODULES	3:35	IVA			
• C/O & RELEASE SATELLITE NO. 2	1:10	IVA			
• RENDEZVOUS TO SATELLITE NO. 3	114:00	IVA			
• SERVICE SATELLITE NO. 3	5:45	IVA			
• RENDEZVOUS TO SATELLITE NO. 4	114:00	IVA			
• SERVICE SATELLITE NO. 4	5:45	IVA			
TOTAL	(365.00)				

2267-103B

Fig. 3.4.2 S1- Functions, Time, and Tasks

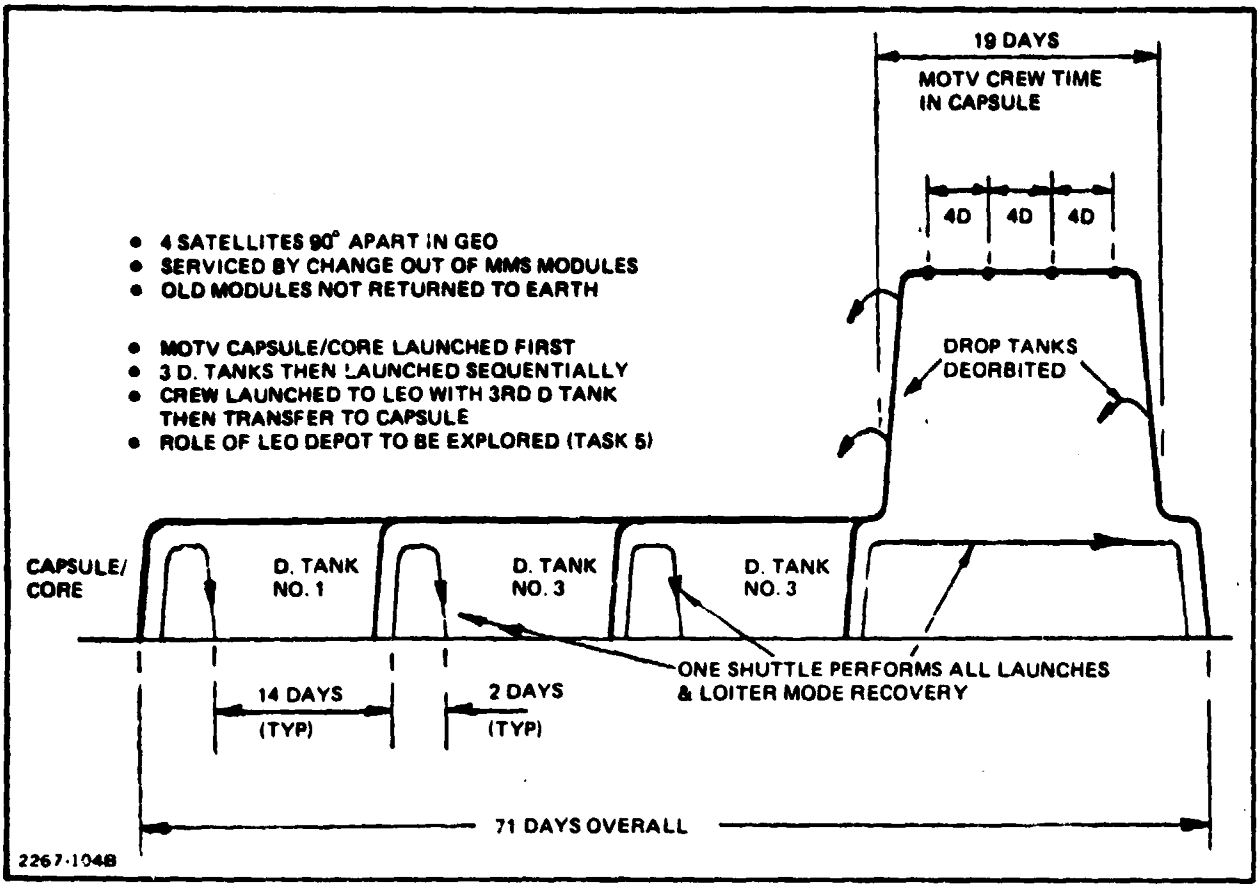


Fig. 3.4.3 S1—Typical Overall Timeline

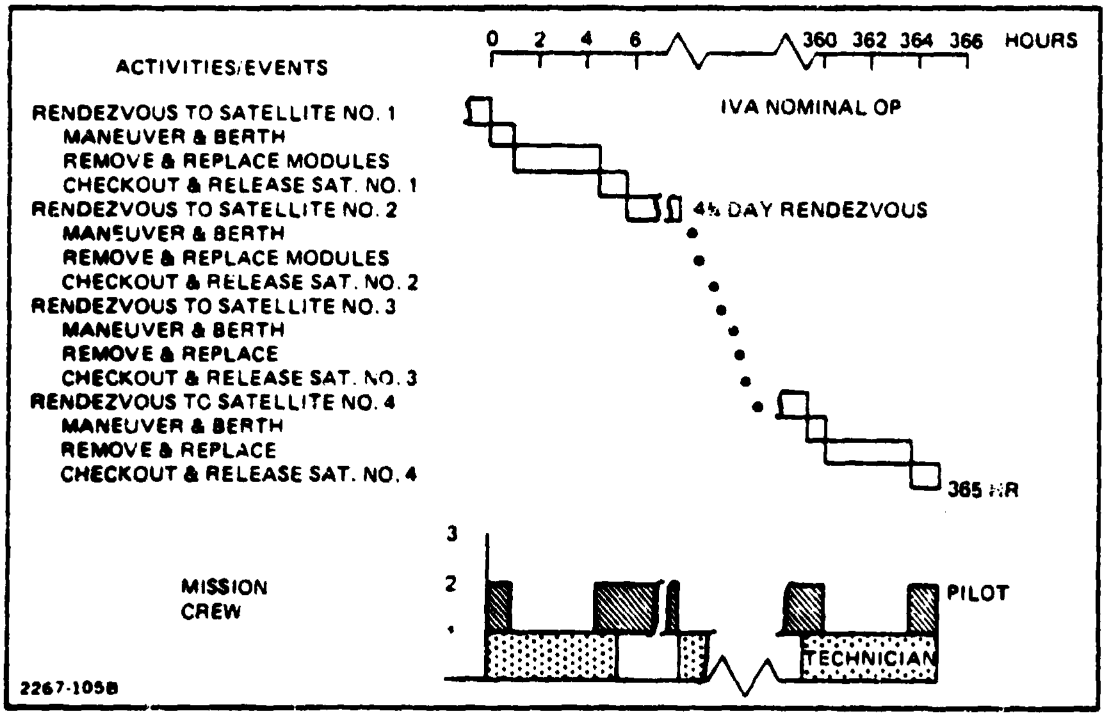


Fig. 3.4.4 S1—Timeline and Crew Requirements

	CREW CAPSULE	PROP'LS'N CORE	DROP TANKS (3)	MISSION EQUIP'T GENERAL PURPOSE	MISSION EQUIP'T DEDICATED
DRY WEIGHT	2775	3502	4425	773	120
CREW/CONSUMABLES RESERVES/RESIDS	418	370 296	 735		
BURNOUT WEIGHT	3193	4168	5130	773	120
MAIN PROP – (CAPACITY) – LOADING ACPS PROP MISC		(17,500) 14,158 2,364 145	(81,810) 58,805		 1684
MOTV WEIGHT	3193	20,835	63,935	773	1804
TOTAL MOTV WEIGHT	90,540				

2267-106B

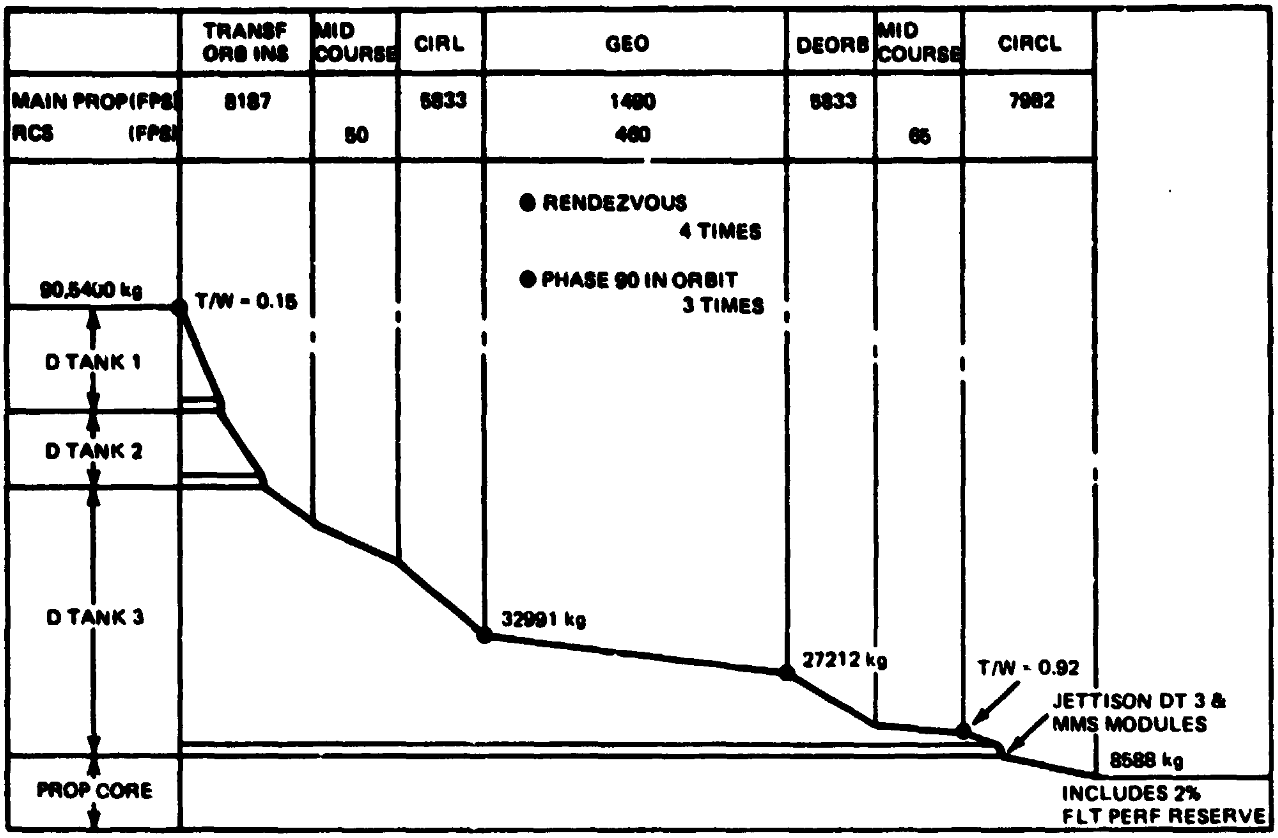
Fig. 3.4.5 S1–Summary Weight Statement, kg

CREW CAPSULE		WEIGHT, kg
STRUCTURE		1113
THERMAL PROT		33
EPS		37
AVIONICS		125
ECLS		296
CREW ACCOM		610
PROPULSION		6
RECOVERY		–
CONTINGENCY	(25%)	555
TOTAL DRY WEIGHT		2775
CREW	(2)	183
CONSUMABLES	(19 DAYS)	255
BURNOUT WEIGHT		3193

NOTES
- MANIPULATORS, ETC., CHARGED TO GEN PURPOSE MISSION EQUIP.
- EPS SUBSYS IS POWER DISTR ONLY – REMAINDER OF SUBSYS IN PROP. CORE

2267-107B

Fig. 3.4.6 S1–Weight Statement (Crew Capsule)



2267-108B

Fig. 3.4.7 Performance Data–Service Mission (S1)

	CREW CAPSULE	PROPULSION CORE	DROP TANKS (3)	TOTALS
MANAGEMENT				0.11
CREW PROVISIONS	0.04			0.04
TURNAROUND			–	2.20
FUEL		0.03	0.11	0.14
DROP TANKS			5.07	5.07
MISSION OPS				2.64
OPS SPARES	0.60	0.40		1.00
STS OPS				108.5
TOTAL				119.7

2267-109B

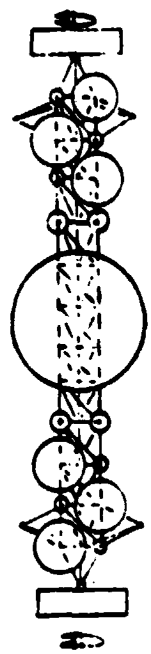
Fig. 3.4.8 S1–Typical Cost per Mission–Service Mission (Constant '79 $ M)

3.5 DESIGN REFERENCE MISSION C3 - PREFAB PLATFORM FOR MOUNTING COMMUNICATIONS ANTENNAS

Mission Description: A space platform is constructed in GEO using Prefab "Dixie Cup" structural members. Upon arrival in GEO the stowed packages of "Dixie Cup" members are unloaded from the MOTV, fabricated into structural members and assembled to form the platform. The various antenna are then mounted to the platform together with a common power supply and electronics. The final configuration is shown in the figure.

Characteristics:

Weight	17,000 kg
Size	
Length	99 m
Width	11 m
Power	
Orbit	GEO
Timeframe	Mid 90s
Life Servicing	30/3 yr



2267-110B

Rationale for MOTV Use:

- Payload weight is beyond the capability of the IUS.
- Manned GEO assembly vs LEO assembly and unmanned transfer has following benefits:
  - effects of transfer g's are minimized saving weight
  - simpler and higher fidelity checkout possible
  - gravity gradient loads reduced by a factor of 200 in GEO minimizing attitude hold propellant requirements during construction
  - antenna alignment is more precise
  - mission success is enhanced.

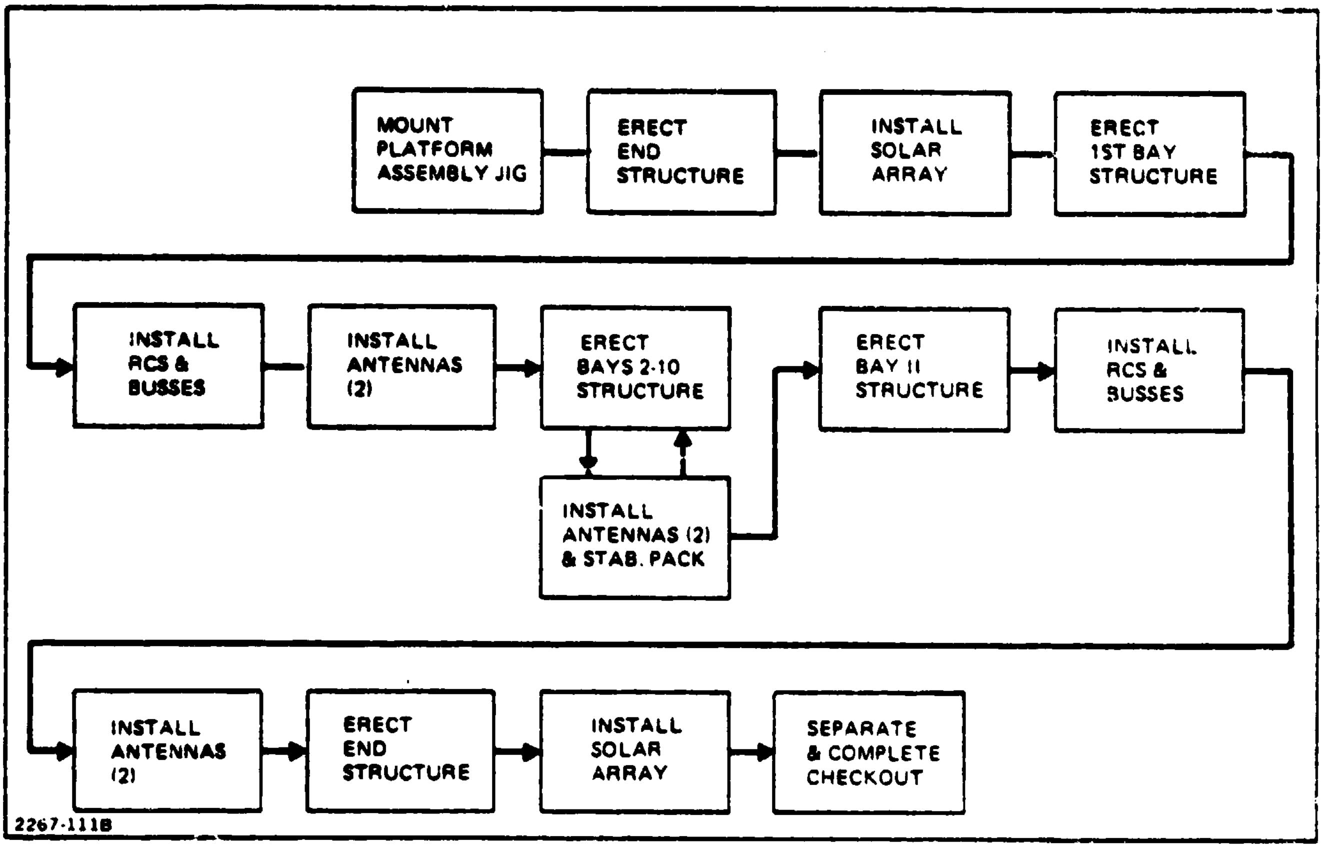


Fig. 3.5.1 C3-Assemble Communication Platform with Prefab Structure

ACTIVITY/FUNCTION	TIME HR. MIN	CREW MODE	NO. CREW	CREW TASK	REMARKS
• MOUNT PLATFORM ASSY JIG	(:60)	IVA		2 MAN CREW	
– ACTIVATE MANIPULATOR SYS	:10		2	+ PILOT	
– MOUNT JIG	:40		2		
– TEST JIG & CLAMPS	: 5		1		
– MOUNT BUS REELS (2)	: 5		2		2 IN 11
• ERECT END STRUCTURE	(:51)				
– INSTALL FITTINGS IN JIG CLAMPS					
– INSTALL LATERAL BEAMS IN JOINT FIT	:36		2		
– INSTALL DIAGONAL BEAMS IN JOINT FIT.					
– CONNECT FWD ENDS OF DIAGONALS 10	:10		2		
– EXTEND BUSSES & CONNECT	: 5		2		2 IN 11
• INSTALL SOLAR ARRAY	(1.00)				
– INSTALL S/A UNIT			2		
– CONNECT S/A TO BUSSES	.50		1		2 IN 11
– DEPLOY S/A	:10		1		
• ERECT 1ST BAY STRUCTURE	(:57)				
– EXTEND JIG (DEPLOY BUSSES)	: 2		2		
– INSTALL JOINT FITTINGS IN REAR JIG CLAMPS			2		
– INSTALL LATERAL BEAMS	.25		2		3 IN 11
– INSTALL LONGITUDINAL BEAMS			2		
– INSTALL DIAGONAL BEAMS	:30		2		
• INSTALL RCS & BUSSES	(1.35)				
– INSTALL RCS BRACES IN BAY STRUCT					
– ATTACH END FITTING	:35		2		2 SIDES IN 11
– CONNECT OUTER ENDS OF BRACES TO JOINT					
– INST. BUSSES	:10		2		
– INSTALL RCS MODULE	:50		2		
• INSTALL ANTENNAS	(1:48)				
– MOUNT ANTENNA UNITS (2)	1:40		2		
– DEPLOY ANTENNAS	: 8		1		1-3 IN, 1-12 IN
– C/O					

2267-112B

Fig. 3.5.2 C3—Functions, Time and Tasks

ACTIVITY/FUNCTION	TIME HR: MIN	CREW MODE	NO. CREW	CREW TASK	REMARKS
• ERECT BAYS 2-10 STRUCTURE	(9:00)				
– RETRACT JIG & RECLAMP	27		1		
– COMPLETE STRUCTURE (SAME AS 1ST BAY STRUCTURE)	8:33		2		
• INSTALL ANTENNAS & STAB. UNIT	10:47				
– MOUNT ANTENNA UNITS (11)	9:10		2		
– DEPLOY ANTENNAS	:47		1		
– MOUNT STABILIZATION UNIT	:50		2		
• ERECT BAY 11 STRUCTURE (SAME AS BAYS 2-10)	(1:00)		–		
• INSTALL RCS & BUSSES (SAME AS 1ST BAY STRUCTURE)	(1:36)		2		
• INSTALL ANTENNAS (4)	(3:34)				
– MOUNT ANTENNA UNITS	3:20		2		
– DEPLOY ANTENNAS	:14		1		2 3 IN 1-12 IN 1-10 IN
• ERECT END STRUCTURE	(:48)				
– INST. DIAG. BEAMS IN FRONT JOINT FIT.	:28		2		
– CONNECT REAR OF BEAMS TO JIG MAIN BEAM					
– EXTEND & CONNECT BUSSES	:5		2		2 IN 11
– STOW BUS REELS	:5		2		2 IN 11
– STOW JIG REAR BEAMS	:10		2		
• INSTALL SOLAR ARRAY (SAME AS 3)	(1:00)		–		
• SEPARATE & COMPLETE CHECKOUT	(2:05)				
– STOW MANIPULATORS	:15		2		
– MANEUVER TO VERIFY SATELLITE CONF	:40		2		
– SUPPORT SPACE-GROUND CHECKOUT	1:10		2		
TOTAL	37:00				

2267-113B

Fig. 3.5.2 C3—Functions, Time and Tasks (Contd)

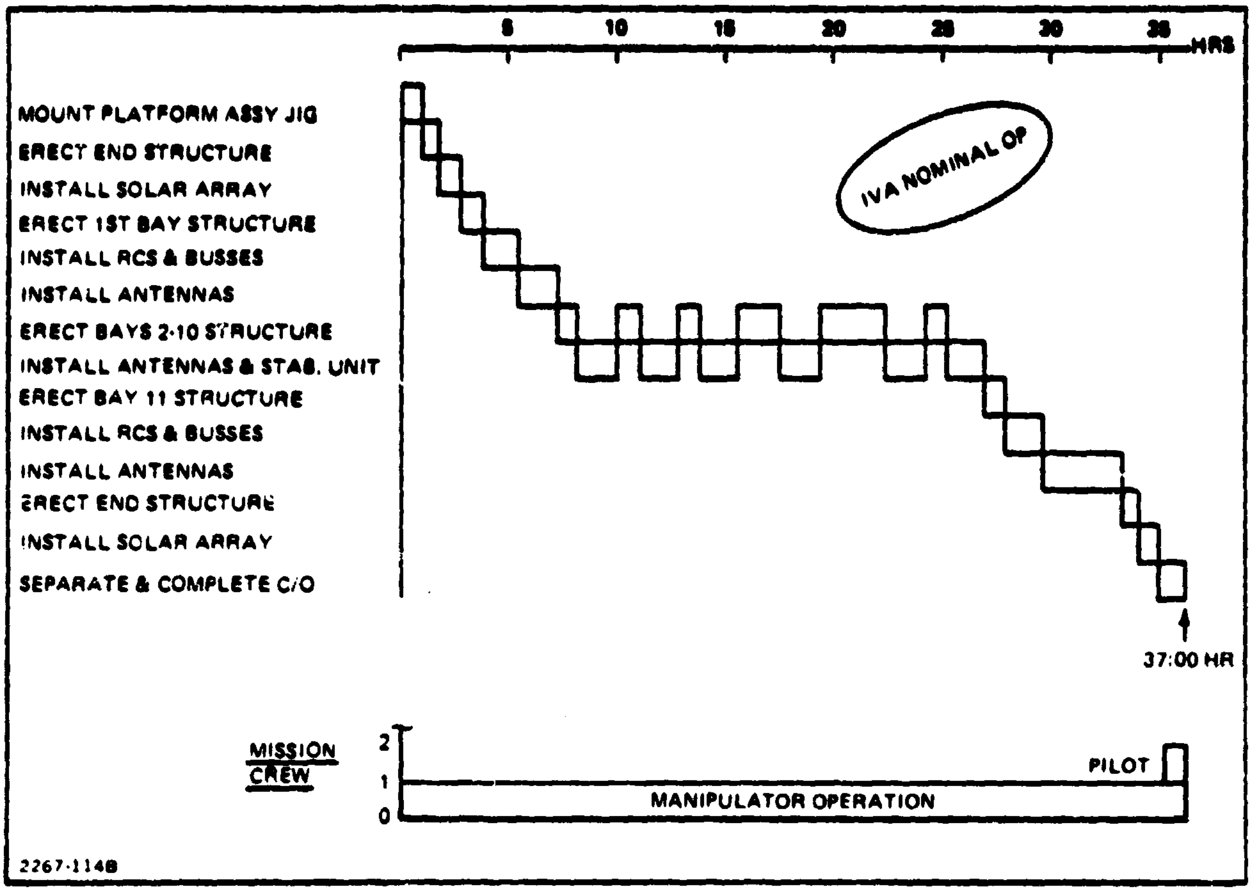


Fig. 3.5.3 C3–Timeline and Crew Requirements

	CREW CAPSULE	PROP'LS'N CORE	DROP TANKS (2)	MISSION EQUIP'T GENERAL PURPOSE	MISSION EQUIP'T DEDICATED
DRY WEIGHT	2775	3116	4426	1038	438
CREW/CONSUMABLES RESERVES/RESIDS	296	244 296	706		
BURNOUT WEIGHT	3071	3656	5130	1036	438
MAIN PROP – (CAPACITY) – LOADING ACPS PROP MISC		(17,500) 16,880 1192 146	(81,810) 68,004		 17,000
MOTV WEIGHT	3071	21 872	73,134	1036	17,438
TOTAL MOTV WEIGHT	116,561				

2367-119B

Fig. 3.5.5 C3 – Weight Statemant (Crew Capsule)

CREW CAPSULE		WEIGHT, kg
STRUCTURE		1113
THEMAL PROT		33
EPS		37
AVIONICS		125
ECLS		296
CREW ACCOM		610
PROPULSION		6
RECOVERY		
CONTINGENCY	(25%)	555
TOTAL DRY WEIGHT		2775
CREW	(2)	163
CONSUMABLES	(6 DAYS)	133
BURNOUT WEIGHT		3071

NOTES

- MANIPULATORS, ETC., CHARGED TO GEN PURPOSE MISSION EQUIP.
- EPS SUBSYS IS POWER DISTR. ONLY – REMAINDER OF SUBYS IN PROP. CORE

2367-116B

Fig. 3.5.5 C3—Weight Statement (Crew Capsule)

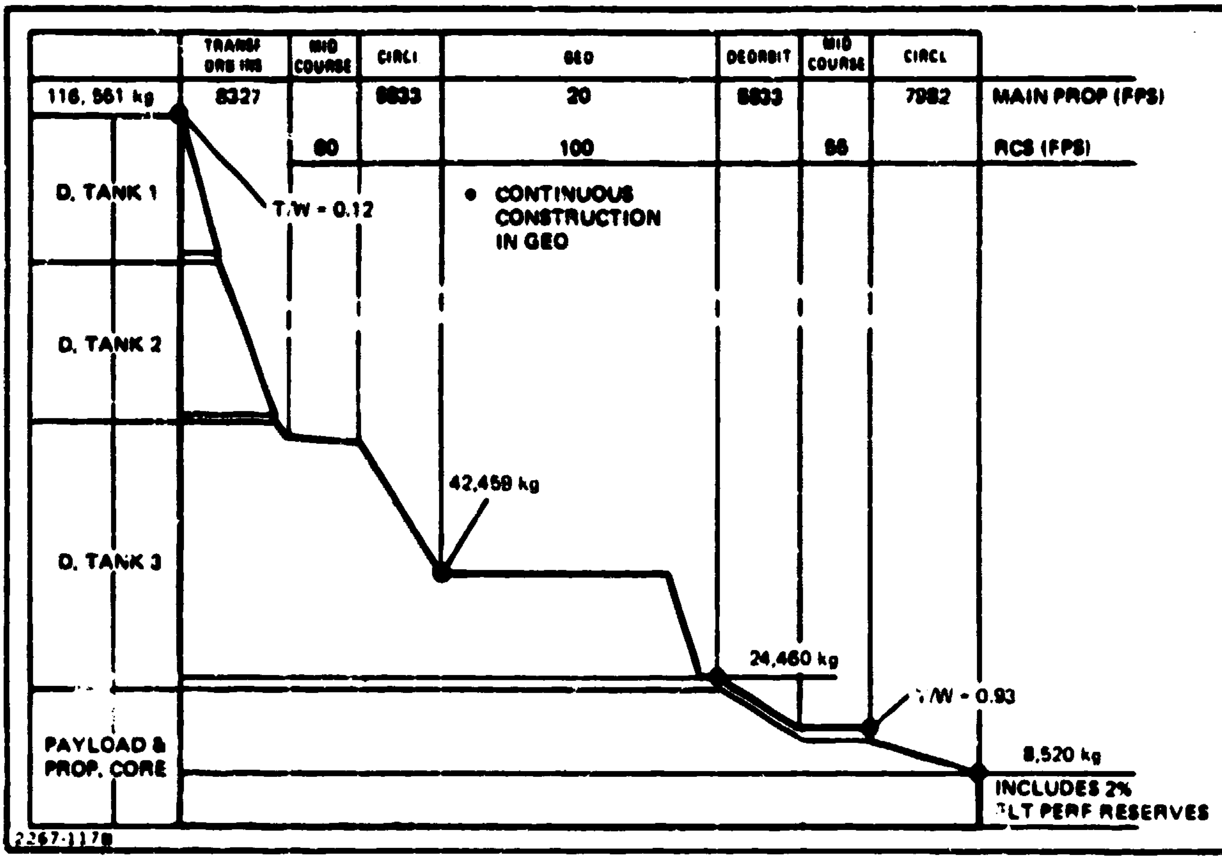


Fig. 3.5.6 C3–Performance Data – Construction Mission

	CREW CAPSULE	PROPULSION CORE	DROP TANKS (3)	TOTALS
MANAGEMENT				0.12
CREW PROVISIONS	0.02		•	0.02
TURNAROUND				2.20
FUEL		0.03	0.13	0.16
DROP TANKS			5.07	5.07
MISSION OPS				3.96
OPS SPARES	0.60	0.40		1.00
STS OPS				123.20
TOTAL				135.73

2267-118B

Fig. 3.5.7 C3–Typical Cost per Mission – (Constant '79 $ M)

3.6 GENERIC MISSION SUMMARY

This subsection consists of Fig. 3.6, Generic Mission Summary; Fig. 3.7, Generic Missions Equipment Requirements, and Fig. 3.8, Generic Mission Weights.

GENERIC MISSION		SCENARIO CHARACTERISTICS								
							ON-ORBIT MAIN	Δv RCS		
CATEGORY	SYMBOL	ORBIT	MISSION HDWR (kg)	ON-ORBIT MISSION EQUIP (kg)	CREW	DURATION (DAYS)	MAIN (fps)	RCS (fps)	ENERGY REQMT (KWHR)	DESCRIPTION
INSPECTION SERVICE & REPAIR	IN1	GEO	510	770	2	4	35	400	373	SCIENTIFIC SATELLITE REVISIT
	$\boxed{\text{S1}}$	GEO	1684	820	2	19	1490	460	1274	MODULAR LEVEL SERVICE
	S2	GEO	2966	878	2	27	1975	590	1780	COMPONENT LEVEL SERVICE & UPDATE
	S3(a)	GEO	2600	980	2	21	1975	590	NA	SERV & UPDATE NUCL PWRD SATS
	(b)	GEO	2000	3461	2	3	35	100	NA	REPLACE NUCL REACTOR
	$\boxed{\text{ER1}}$	GEO	453	810	2	4	35	100	351	EMERGENCY REPAIR (GEO)
	$\boxed{\text{ER2}}$	12 HR/63	272	1462	2	4	235	100	373	EMERGENCY REPAIR (HEO)
	R1	12 HR/63	4100	1230	2	2	235	100	281	FAILED SATELLITE
OPERATION OF A LARGE SPACE SYSTEM	OP1	GEO	550	1176	2	16	35	100	1249	TENDED STO
	P1	LLO	1683	716	2	4	35	100	373	3 MAN CREW ROTATION/RESUPPLY
	P2	GEO	4485	754	2	4	35	100	456	10 MAN CREW ROTATION/RESUPPLY
	P3	GEO	16,819	924	2	4	35	100	652	30 MAN CREW ROTATION/RESUPPLY
	P4	DEEP SPACE	3364	2108	2	30	35	100	2969	6 MAN CREW ROTATION/RESUPPLY
DEBRIS REMOVAL	$\boxed{\text{DR1}}$	GEO	5500	934	2	9	1460	370	687	REMOVE DEBRIS FROM A 45° SECTOR OF GEO
CONSTRUCTION	C1	GEO	10,000	867	2	3	0	100	300	UNFOLD WIRE WHEEL ANTENNA
	C2		16,000	1112	2	6	20	100	490	UNFOLD COMMUN PLATFORM
	$\boxed{\text{C3}}$		17,000	1462	2	6	20	100	519	PREFAB COMMUN PLATFORM
	C4		15,000	1462	2	7	20	100	578	AUTOFAB COMMUN PLATFORM
	C5		110,535	9090	3	14/5/5/5			1081/570 EA	AUTOFAB SPDA
	C6		NONE	750	2	17	35	580	1980	MODULAR ASSY SPDA
UNMANNED CARGO	UC	VARIOUS	15,000 55,000	N/A	NONE	–	–	–	–	SECONDARY ROLE

SYMBOLS

IN = INSPECTION
S = SERVICE
ER = EMERG REPAIR
R = RETRIEVAL
OP = OPER LG SPACE SYSTEM

P = PASS. TRANSPORT
DR = DEBRIS REMOVAL
C = CONST
UC = UNMAN CARGO

☐ DESIGN REFERENCE MISSIONS

2267-119B

Fig. 3.6 Generic Mission Summary

EQUIPMENT	INSPECTION, SERVICE & REPAIR					
	IN1	S1	S2	S3(a)	S3(b)	ER1
• MANIPULATORS						
- REACH (m)	2.5	2.0	2.5	2.5	2.5	2.5
- DOF	7	7	7	7	7	7
- NO. REQD.	2	2	2	2	2	2
- UNIT WGT (kg)	195	178	185	195	195	185
• STABILIZER FOR BERTHING						
- REACH (m)	2	2	2	2	2	2
- DOF	4	4	4	4	4	4
- NO. REQD.	1	1	1	1	1	1
- UNIT WGT (kg)	50	50	50	50	50	50
• EVA SUITS						
- TYPE/NO. REQD.	GEO/2	GEO/2	GEO/2	GEO/2	GEO/2	GEO/2
- NO. EVA'S PERMISSION (NORM OR EMERG)	3	3	3	3	3	3
- ENDURANCE TIME/EVA (HR)	6	6	6	6	6	6
- TETHER	YES	YES	YES	YES	YES	YES
- UNIT WGT (kg)	137.5	137.5	137.5	137.5	137.5	137.5
• DOCKING						
- TYPE	BERTH	BERTH	BERTH	BERTH	BERTH	BERTH
- NO. REQD.	1	1	1	1	1	1
- UNIT WGT (kg)	110	110	110	110	110	110
• C/O & CALIB EQUIP.						
– TYPE OF C/O REQD.	SUBSYST C/O	MMS + ANT. FEED C/O	COMP. + ANT. FEED C/O	COMP. + ANT FEED C/O	–	ANT. FEED + COMP. C/O
– CRYO FLUID REPLENISHMENT	.	.	.		–	.
– WGT ALLOCATION (kg)	10	10	10	30	–	10
• EQUIP. STOWAGE RACKS, CONTAINERS						
– TYPE	EXP TRAY RACK	MMS HOLDERS	TWT HOLDERS	BLACK BOX RACKS	–	ANT.+EQUIP. HOLD.
– NO. REQD.	1	12	40		–	2 HOLDERS
– SIZE (m)	1 x 1	1.2x1.2x0.46	0.4x0.6x0.9			30 m ANT.+COMP.
– UNIT WGT (kg)	20	8	3	200	–	20

2267-120(1)B

FOLDOUT FRAME 1

		OPER OF A LARGE SPACE SYST		DEBRIS REMOVAL	CON	
ER2	R1	OP1	P1-P4	DR1	C1	C2
3.0 7 3 210	2.5 7 2 195	2.5 7 2 195	– – – –	4.0 7 2 237	4 7 1 237	4 7 2 237
2 4 1 50	2 4 1 50	– – – –	– – – –	2 4 1 50	– – – –	– – – –
EO/2 6 YES 137.5	GEO/2 3 6 YES 137.5	GEO/2 3 6 YES 137.5	LEO/1+1CABIN/MAN 1 EMERGY 6 NO 137.5	GEO/2 3 6 YES 137.5	GEO/2 3 6 YES 137.5	GEO/2 3 6 YES 137.5
BERTH 1 110	BERTH 1 110	INT'L DOCK 1 408	INT'L DOCK 1 408	BERTH 1 110	BERTH 1 110	BERTH 1 110
RV SAT. BSYST C/O - 10	SAFING & C/O . 10	SUBSYST + INSTR C/O 5 kg CH2+5 kg CH4 10 + 10 = 20	- - - -	SAFING & C/O . 10	ANT.FEED + ANT.PATTERN C/O . 10	SUBSYST + ANT. FEED C/O . 10
NSOR MOD + S/A + RCS HOLDERS ARIOUS 20	P/L RET. LATCHES 4 LATCHES - 20	SAMP TRAY + RCS + SUBSYS LATCHES + BRACKETS VARIOUS 40	RESUPPLIES 49 LATCHES 16 BOXES (3 EA) 5	STOW.RACK 1 3 m TRIANGLE 100	– – – –	17 ANT.PACKAGES + 2 S/A + SS 60 LATCHES VARIOUS 5

FOLDOUT FRAME 2

...TION				UNMANNED CARGO
C3	C4	C5	C6	UC
4	4	4	25	–
7	7	7	7	–
2	2	2	2	–
237	237	237	502	–
2	–	2	–	–
4	–	4	–	–
1	–	1	–	–
50	–	50	–	–
2	GEO/2	GEO/3	GEO/2	–
	3	3	3	–
6	6	6	6	–
YES	YES	YES	YES	–
137.5	137.5	137.5	137.5	–
BERTH	BERTH	BERTH	BERTH	–
	1	1	1	–
10	110	110	110	–
YST +	SUBSYST +	SUBSYST	SUBSYST	–
FEED C/O	ANT.FEED C/O	C/O	C/O	–
-	-	-	-	–
10	10	10	10	–
			–	–
AS	SAME AS			
	C2	TBD	–	–
OUS	VARIOUS		–	–
5	5		–	–

Fig. 3.7 Generic Missions Equipment Requirements (Sheet 1 of 2)

EQUIPMENT	INSPECTION, SERVICE & REPAIR						
	IN1	S1	S2	S3(a)	S3(b)	ER1	
• FIXTURES/JIGS							
· TYPES	–	–	–	–	–	–	
· WGT (kg)	–	–	–	–	–	–	
• BEAM BUILDERS							
· NO. REQD.	–	–	–	–	–	–	
· BEAM SIZE (m)	–	–	–	–	–	–	
· UNIT WGT (kg)	–	–	–	–	–	–	
• EVA TOOLS							
· TYPES	TOOL LIST	TOOL LIST	TOOL LIST	TOOL LIST	TOOL LIST	TOOL LIST	T
· EST TOTAL WGT (kg)	25	25	25	25	25	25	
• SPEC. DIAGNOSTIC EQUIP.							
· TYPE	–	–	–	PART. DET	PART. DET	ELECT. ANALYZER	E
· EST WGT (kg)	–	–	–	10	10	20	
• AIRLOCK							
· TYPE	–	–	–	–	–	–	
· UNIT WGT (kg)	–	–	–	–	–	–	
• TELEOPERATORS/PROP STAB.UNITS (PSU)					TELEOPER.		P
· CONTROL STATION LOCATION/NO.REQD.	–	–	–	–	MOTV/1	–	M
· MAX RANGE (m)	–	–	–	–	1000	–	
· EST UNIT WGT (kg)	–	–	–	–	1100/1481	–	
• CHERRY PICKER							
·OPEN/CLOSED	–	–	–	–	–	–	
· NO.MANIP. ARMS/REACH (m)	–	–	–	–	–	–	
·NO. GRAPPLERS/REACH (m)	–	–	–	–	–	–	
· EST WGT (kg)	–	–	–	–	–	–	
• STORM SHELTER							
· NO. OCCUPANTS				–	–		
· WGT (kg)				–	–		
• OTHER				–	–		

2267-120B(2)

FOLDOUT FRAME

		OPER OF A LARGE SPACE SYST		DEBRIS REMOVAL	CONSTRU		
ER2	R1	OP1	P1-P4	DR1	C1	C2	
– –	– –	– –	– –	– –	3m D/A TURNTBL 50	DEPL. MAST & GRAPPLER 20	ASSY STR C
– – –	– – –	– – –	– – –	– – –	– – –	– – –	
L LIST 25	TOOL LIST 25	TOOL LIST 25	TOOL LIST 25	TOOL LIST 25	TOOL LIST 25	TOOL LIST 25	TOOL
CT. & REMOTE ANNERS 30	REMOTE SCANNERS 30	ELECT. ANALYZER 20	– –	– –	– –	– –	
– –	– –	– –	– –	– –	– –	– –	
V/1 1000 612	PSU MOTV/1 1000 612	– – –	– – –	– – –	– – –	– – –	
– – – –	– – – –	– – – –	– – – –	– – – –	– – – –	– – – –	
			P4 ONLY 6 1369				

FOLDOUT FRAME 2

'RUCTION				UNMANNED CARGO
C3	C4	C5	C6	UC
SSY JIG + 'R CONT 50	FAB/ASSY JIG 100	CORNER ASSY JIG + BEAM SP 100	– – –	– – –
– – –	1 1 7500	1 1 7500	– – –	– – –
OOL LIST 25	TOOL LIST 25	TOOL LIST 25	TOOL LIST 25	– –
– –	– –	– –	– –	– –
– –	– –	– –	– –	– –
– – –	– – –	– – –	– – –	– – –
– – – –	– – – –	– – – –	– – – –	– – – –
				– –

FOLDOUT FRAME 3

Fig. 3.7 Generic Missions Equipment Requirements (Sheet 2 of 2)

ITEM	INSPECTION, SERVICE & REPAIR											
	INSPECTION IN1		SERVICE S1		SERVICE S2		SERVICE S3(a)		SERVICE S3(b)		EMERG REPAIR ER1	
	DE-PLOY	RE-TURN	DE-PLOY	RE-TURN	DE-PLOY	RE-TURN	DE-PLOY	RE-TURN	DE-PLOY	RE-TURN	DE-PLOY	RE-TURN
• MISSION HDWR												
– REPLACEMENT MODULES, COMPONENTS, SPARES, ETC.	450	450	1684	1684	1560	1560	2000	2000	2000 (NUCLEAR CORE)	–	403	350
– SATELLITE	–	–	–	–						–		
– SAT. SERVICING, RCS, ETC.	60	10	–	–	1406	234	400	100		–	50	8
• ON-ORBIT MISSION EQUIP.												
– MANIPULATORS	390	390	356	356	390	390	390	390	390	320	390	390
– STABILIZER FOR BERTHING	50	50	50	50	50	50	50	50	50	50	50	50
Ⓐ – EVA & IN-CABIN SUITS	275	275	275	275	275	275	275	275	275	275	275	275
Ⓐ – DOCKING/BERTHING	110	110	110	110	110	110	110	110	110	110	110	110
– C/O & CALIB EQUIP.	10	10	10	10	10	10	30	30	10	10	10	10
– EQUIP. STOW. RACKS, CONTAIN.	20	20	96	96	120	120	200	200	120	120	40	40
– FIXTURES & JIGS	–	–	–	–	–	–	–	–	–	–	–	–
– BEAM BUILDERS	–	–	–	–	–	–	–	–	–	–	–	–
– EVA TOOLS	25	25	25	25	25	25	25	25	25	25	25	25
– SPEC DIAG EQUIP.	–	–	–	–	–	–	10	10	10	10	20	20
– AIR LOCK	–	–	–	–	–	–	–	–	–	–	–	–
– TELEOPER./PROP. STAB. UNITS	–	–	–	–	–	–	–	–	2581	800	–	–
– CHERRY PICKER	–	–	–	–	–	–	–	–	–	–	–	–
– STROM SHELTER	–	–	–	–	–	–	–	–	–	–	–	–
– OTHER												
• CREW MODULE	2497	2497	2638	2638	2713	2713	2657	2657	2488	2488	2497	2497
• CONTINGENCY **	679	679	689	689	704	704	731	731	1347	901	689	689
TOTAL	4181	431	5548	5548	6978	5806	6493	6193	9000	4774	4174	4079

2267-121B(1)

Ⓐ WEIGHT INCLUDED IN CREW CAPSULE SUBTOTAL

FOLDOUT FRAME

							OPER. OF A LARGE SPACE SYSTEM			
REPAIR 1	EMERG REPAIR ER2		RETRIEVAL R1		OPER LG SPACE SYS OP1		PASSING TRANS P1	
RE-TURN	DE-PLOY	RE-TURN	DE-PLOY	RE-TURN	DE-PLOY	RE-TURN	DE-PLOY	RE-TURN
350	222	187	–	–	500	500	1433	435
			–	4100	–	–		
8	50	8	–	–	50	8	250	42
390	420	420	390	390	390	390	–	–
50	50	50	50	50	–	–	–	–
275	275	275	275	275	275	275	283	283
110	110	110	110	110	408	408	408	408
10	10	10	10	10	10	10	–	–
40	40	40	80	80	40	40	–	–
–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–	–
25	25	25	25	25	25	25	25	25
20	30	30	30	30	20	20	–	–
–	–	–	–	–	–	–	–	–
–	612	612	100	–	–	–	–	–
–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–	–
2497	2497	2497	2478	2478	2910	2910	3558	3558
689	827	827	724	699	751	751	798	798
4079	4683	4606	3877	7852	4696	4654	6064	4858

FOLDOUT FRAME

2

Fig. 3.8 Generic Mission Weights–kg (Sheet 1 of 2)

ITEM	OPERATION OF A LARGE SPACE SYSTEM — PASSENG TRANS P2 DEPLOY	PASSENG TRANS P2 RETURN	PASSENG TRANS P3 DEPLOY	PASSENG TRANS P3 RETURN	PASSENG TRANS P4 DEPLOY	PASSENG TRANS P4 RETURN	DEBRIS REMOVAL DR1 DEPLOY	DEBRIS REMOVAL DR1 RETURN	CONSTRUCTION C1 DEPLOY	CONSTRUCTION C1 RETU
• MISSION HDWR										
– REPLACEMENT MODULES COMPONENTS, SPARES, ETC	3818	1361	14319	5064	2864	867			–	–
– SATELLITE	–	–	–	–	–	–	(5500) Ⓓ	–	10000	–
– SAT. SERVICING, RCS, ETC	667	112	2800	420	500	83			–	–
• ON-ORBIT MISSION EQUIP.										
– MANIPULATORS	–	–	–	–	–	–	474	474	237	23
– STABILIZER FOR BERTHING	–	–	–	–	–	–	50	50	–	–
– EVA & IN-CABIN SUITS	321	321	491	491	306	306	276	276	276	27
– MMUs	–	–	–	–	–	–	–	–	270	27
– DOCKING/BERTHING	408	408	408	408	408	408	110	110	110	11
– C/O & CALIB EQUIP.	–	–	–	–	–	–	10	10	10	1
– EQUIP. STOW. RACKS, CONTAIN.	–	–	–	–	–	–	100	100	–	–
– FIXTURES & JIGS	–	–	–	–	–	–	–	–	50	5
– BEAM BUILDERS	–	–	–	–	–	–	–	–	–	–
– EVA TOOLS	25	25	25	25	25	25	25	25	25	2
– SPEC DIAG EQUIP.	–	–	–	–	–	–	–	–	–	–
– AIR LOCK	–	–	–	–	–	–	–	–	–	–
– TELEOPER/PROP. STAB. UNITS	–	–	–	–	–	–	–	–	–	–
– CHERRY PICKER	–	–	–	–	–	–	–	–	–	–
– STORM SHELTER	–	–	–	–	1369	1369	–	–	–	–
– OTHER										
• CREW MODULE	4329	4329			4505	4505	2544	2544	2489	248
• CONTINGENCY Ⓒ	798	798			1140	1140	720	720	[illegible]	63
TOTAL	9637	6615			10403	7989	3923	3923	134[illegible]	344

Ⓐ WEIGHT INCLUDED IN CREW CAPSULE SUBTOTAL
Ⓑ 1ST C5 FLT; REMAINING 3 FLTS HAVE 28,898 kg DEPLOYED
Ⓒ 25% OF ON-ORBIT MISSION EQUIP. PLUS CREW MODULE LESS CREW AND CONSUMABLES
Ⓓ PAYLOAD BROUGHT FROM GEO TO GEO + 2000 N MI

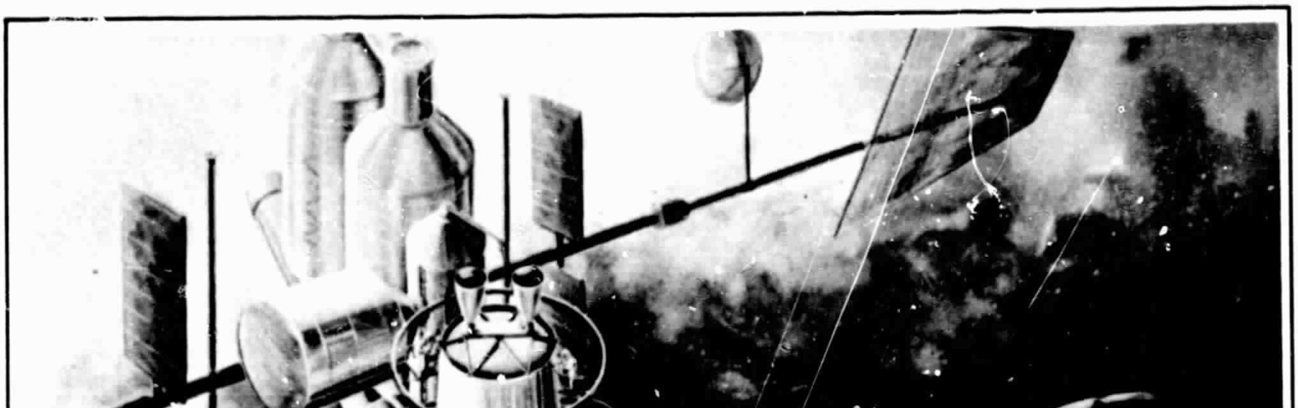
2267-121(2)B

FOLDOUT FRAME

...CTION	CONSTRUCTION C2		CONSTRUCTION: CONSTRUCTION C3		CONSTRUCTION: CONSTRUCTION C4		CONSTRUCTION C5		CONSTRUCTION C6		UNMANNED CARGO UC	
RETURN	DEPLOY	RETURN	DEPLOY	RETURN	DEPLOY	RETURN	DEPLOY	RETURN	DEPLOY	RETURN	DEPLOY	RETURN
–	–	–	–	–	–	–	40	–	–	–		
–	16000	–	17000	–	16000	–	(23841) 5	–	–	–		
–	–	–	–	–	–	–	–	–	–	–		
237	474	474	474	474	474	474	474	474	390	390		
–	–	–	50	50	–	–	–	–	50	50		
275	275	275	275	275	275	275	283	283	275	275		
270	–	–	270	270	270	270	270	270	–	–		
110	110	110	110	110	110	110	110	110	110	110		
10	10	10	10	10	10	10	10	10	10	10		
–	300	300	300	300	300	300	20	20	–	–		
50	20	20	50	50	100	100	100	–	–	–		
–	–	–	–	–	–	–	7500	–	–	–		
25	25	25	25	25	25	25	25	–	25	25		
–	–	–	–	–	–	–	–	–	–	–		
–	–	–	–	–	–	–	–	–	–	–		
–	–	–	–	–	–	–	–	–	–	–		
–	–	–	–	–	–	–	–	–	–	–		
–	–	–	–	–	–	–	–	–	–	–		
2488	2516	2516	2516	2516	2526	2526	3387	3387	2619	2619	5000	5000
636	762	762	782	782	2667	777	2749	843	674	674	TO	TO
3446	20107	4107	21207	4207	28591	4191	38146	4734	3768	3768	50,000	20,000

Fig. 3.8 Generic Mission Weights—kg (Sheet 2 of 2)

FOLDOUT FRAME 2



4 - TURNAROUND & SUPPORT REQUIREMENTS

This section describes the OTV/MOTV turnaround scenario which our study indicated is the most effective method of checking out and refurbishing the orbital transfer vehicle between missions and preparing it to perform subsequent missions. The information is intended to be used as a guide for the MOTV users operations planning and should serve as the basis for determining the launch site and LEO Space Operations Center support as well as the impact turnaround has on the OTV/MOTV configuration. This section is structured to provide the user with an overview of the recommended turnaround scenario, the ground rules and assumptions used in developing the turnaround operations; a definition of the subsystem, handling, transportation, functional and servicing requirements and; finally, the support required to implement the operations described.

Although the turnaround scenario presented is sensitive to the traffic model assumed, the specific turnaround requirements defined are insensitive to the traffic assumed and should assist the user in developing alternate scenarios which would accommodate other traffic patterns and assumptions. The documents which justify and support the scenario, requirements and other information presented in the remainder of this section are listed in appendix "A".

4.1 TURNAROUND SCENARIO

Figure 4.1 illustrates the recommended turnaround scenario, a mix of SOC and ground turnaround activities, superimposed on a projected OTV/MOTV traffic pattern. The traffic pattern is in concert with the ground rules, paragraph 4.2, assuming a 1992 IOC, a 3/1 ratio of OTV/MOTV missions, a ratio of two short duration missions (ER-1 type) for each long duration mission (S-1 type) and a build-up of from 3 to 6 flights per year in 4 years. For this scenario we propose to perform post flight and or periodic maintenance at SOC, and perform major maintenance, overhaul, on the ground. Specifically:

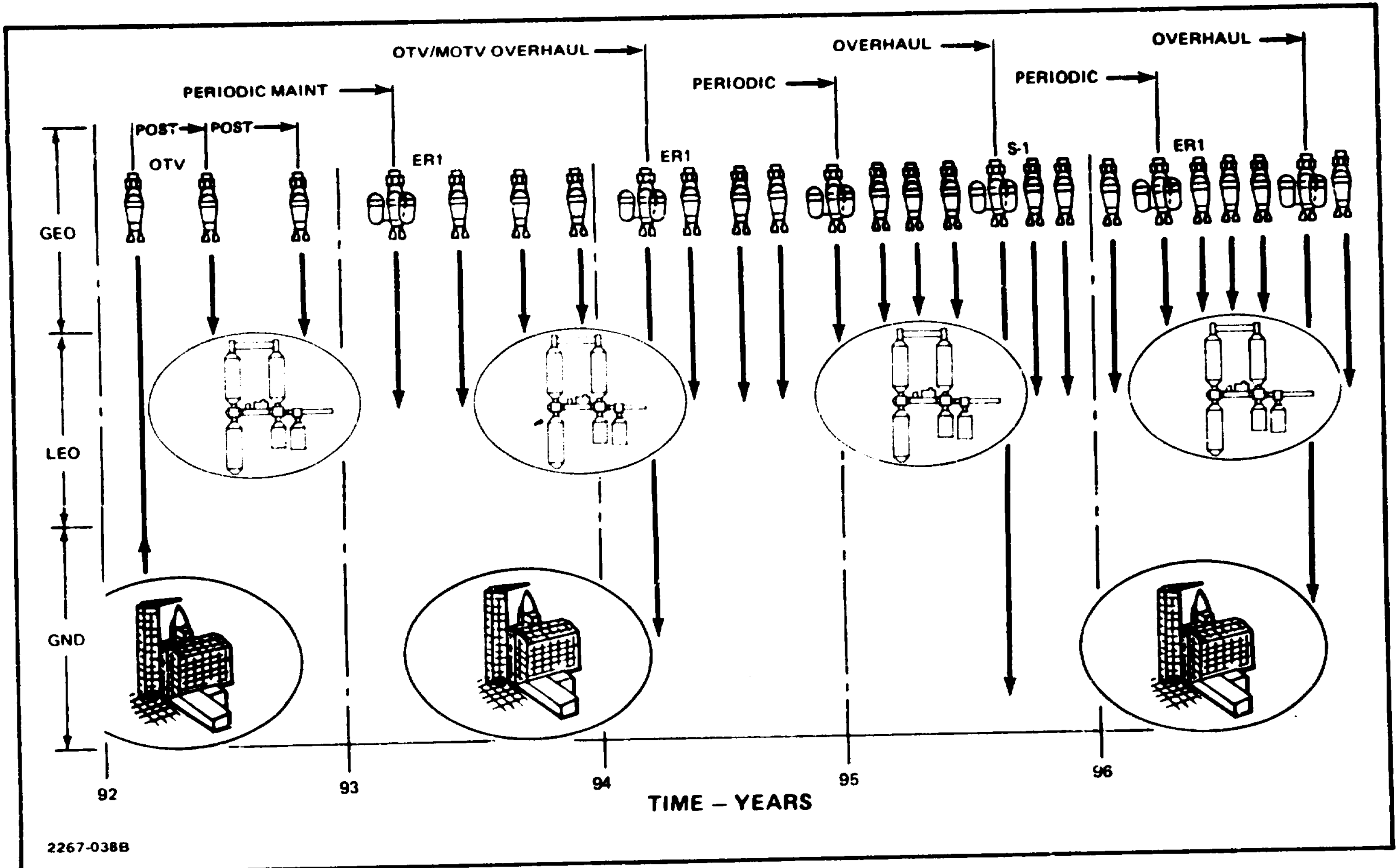


Fig. 4.1 OTV/MOTV Five-Year Projected Traffic and Turnaround Maintenance Cycles

- Post Flight (PF) only - This mode of operation assumes the operational flight instrumentation system (OFI) indicates no subsystem anomalies are experienced during the GEO mission and a post flight safety and damage inspection uncovers no problems. The vehicle is therefore serviced at SOC, configured for the next mission, fueled and overall systems checked out (c/o) for initiation of the next mission. This is the minimum maintenance mode in which no refurbishment is conducted. It will be the standard mode for every flight except those requiring periodic maintenance or overhaul.

- Periodic Maintenance - This mode assumes limited maintenance at SOC, consisting of on-line calibration or c/o of navigation hardware and or software as required and or replacement of one or two LRU modules. The activities include those discussed under PF plus the specific limited maintenance items. For the traffic model shown, periodic maintenance would occur on an average of about every fourth flight.

- Overhaul - This mode includes a complete ground inspection, performance checks of all subsystems, calibration of all sensors, changeout of limited life items (including engines) and required vehicle modes as well as replacement of discrepent or suspicious LRU's. It is paced by the engine-limited lifetime, is conducted on the ground and for the traffic model illustrated occurs about every eighth flight.

4.2 GROUND RULES & ASSUMPTIONS

The following ground rules and assumptions were used in developing the scenario discussed in paragraph 4.1 and the remainder of this section.

4.2.1 Turnaround operations are defined as including all the activities between the orbit transfer ignition from GEO to LEO of the returning MOTV at the end of one GEO mission, to the orbit transfer burn from LEO to GEO, initiating the start of the next GEO mission.

4.2.2 The 1-1/2 Stage All Propulsive OTV/MOTV with the two-man functional minimum crew module is the baseline configuration. Figure 1.2.1 artist's rendition of a two drop tank configuration was used to develop turnaround requirements.

4.2.3 The turnaround requirements will accommodate all of the generic OTV/MOTV missions (Fig. 4.2).

4.2.4 The standard STS is the orbital transfer vehicle.

GENERIC MISSION		SCENARIO CHARACTERISTICS				
CATEGORY	SYMBOL	ORBIT	MISSION HDWR, Kg	CREW *	DURATION, DAYS	DESCRIPTION
INSPECTION SERVICE & REPAIR	IN1	GEO	510	2	4	SCIENTIFIC SATELLITE REVISIT
	$\boxed{S1}$	GEO	1684	2	19	MODULAR LEVEL SERVICE
	S2	GEO	2966	2	27	COMPONENT LEVEL SERVICE & UPDATE
	S3(a)	GEO	2600	2	21	SERV & UPDATE NUCL PWRD SATS
	S3(b)	GEO	2600	2	3	REPLACE NUCL REACTOR
	$\boxed{ER1}$	GEO	453	2	4	EMERGENCY REPAIR (GEO)
	$\boxed{ER2}$	12 HR/63	272	2	4	EMERGENCY REPAIR (HEO)
	R1	12 HR/63	4100	2	2	FAILED SATELLITE
OPERATION OF LARGE SPACE SYSTEM	OP1	GEO	440	2	16	TENDED STO
	P1	GEO	1683	2	4	3 MAN CREW ROTATION/RESUPPLY
	P2	GEO	4485	2	4	10 MAN CREW ROTATION/RESUPPLY
	P3	GEO	16,819	2	4	30 MAN CREW ROTATION/RESUPPLY
	P4	DEEP SPACE	3364	2	30	6 MAN CREW ROTATION/RESUPPLY
DEBRIS REMOVAL	$\boxed{DR1}$	GEO	550	2	9	REMOVE DEBRIS FROM 45° SECTOR OF GEO
CONSTRUCTION	C1	GEO	10,000	2	3	UNFOLD WIRE WHEEL ANTENNA
	C2		16,000	2	6	UNFOLD COMMUN PLATFORM
	$\boxed{C3}$		17,000	2	6	PREFAB COMMUN PLATFORM
	C4		15,000	2	7	AUTOFAB COMMUN PLATFORM
	C5		110,535	3	14/5/5/5	AUTOFAB SPDA
	C6		-	2	17	MODULAR ASSY SPDA
UNMANNED CARGO	UC	VARIOUS	15,000 55,000	NONE		SECONDARY ROLE

2267-040B

SYMBOLS

IN = INSPECTION
S = SERVICE
ER = EMERG REPAIR
R = RETRIEVAL
OP = OPER. LG SPACE SYSTEM
P = PASS. TRANSPORT
DR = DEBRIS REMOVAL
C = CONST
UC = UNMAN. CARGO

□ DESIGN REFERENCE MISSIONS

* MIN. TO PERFORM TASKS IVA

Fig. 4.2 Generic Mission Summary

4.2.5 OTV/MOTV IOC is 1992; OTV/MOTV Flts = 3/1; OTV/MOTV traffic will build up to six flts/year in six years.

4.2.6 KSC is the launch site and ground turnaround base.

4.2.7 Ground turnaround operations, overhaul, will be conducted on a two, eight-hour shift, five-day week basis to handle the scheduled and unscheduled (corrective) maintenance. Contingencies will be handled with overtime as required.

4.2.8 The SOC LEO OTV/MOTV Turnaround Facility will have the following capability:

- Power, spacecraft handling equipment, cranes, and IVA/EVA equipment to perform turnaround tasks
- Ground support equipment required for turnaround
- Voice, data, and command link with the ground maintenance control center
- Logistics capability for storing LRU's, test equipment, tools and mission equipment
- Logistics capability for storing crew capsule, propulsion core module, fuel tanks, other fluids, and required mission consumables
- Pressurized access between the MOTV crew module and the SOC will be provided during normal crew exchange and servicing operations. It may also be considered for use during periods of crew module stowage to provide extra habitability volume when both the SOC crew and the MOTV crew are present
- The MOTV/OTV turnaround operations will include EVA operations. This could involve the use of one EVA crewman plus one EVA crewman as backup. Crew workload and task assignments should consider this function.
- SOC will provide sufficient support provisions for the MOTV crew so as not to require a special Shuttle flight for returning the crew to earth
- SOC crew size is eight men with two men required for housekeeping and six men available for other activities, including OTV/MOTV turnaround.
- SOC and MOTV crews are on a 90-day rotation centers

4.2.9 The OTV/MOTV configuration will have the following characteristics:

- Primary structure, exterior structural skin and meteoroid bumper are aluminum with no sharp corner or edges

- Loose LRU replacement hardware shall be captured or tethered
- LRU's shall
  - Be reasonably sized
  - Have standard envelopes (avionics)
  - Have minimum interfaces
  - Include alignment pins
  - Incorporate quick make/release mechanism
  - Incorporate isolation valves (fluid)
  - Incorporate self sealing disconnects (fluid)

4.2.10 The OTV/MOTV Avionics System will include the following features:

- Orbital Flight Instrumentation (OFI) package which can monitor the health, status of all subsystems and isolate anamolies to the LRU level
- All avionics subsystems instrumented adequately to provide in-flight operational performance data
- In place calibration and adjustment will be maximized
- Data from checkout, fault isolation, status, and flight is transmitted to the ground computer which in turn provides maintenance support to SOC.

4.2.11 The OTV/MOTV propulsion subsystem will include the following features:

- All main engine parallel redundant paths are "on line" and can be checked in flight
- Welding is the primary method for connecting fuel lines to each other and to valves; tanks are also weldment assemblies; inter-module connections are of the quick disconnect self-sealing type
- All main engine components, except the thrust chambers and turbo pumps, are line replaceable units (LRU)
- Provisions for internal inspection of the main engine thrust chamber and turbo pump components are available

- All propulsion components except engine thrust chambers, turbo pump, ignition system, and other limited-life items will have a time/life cycle good for approximately 15 missions
- The engine will have at least a 5 year time/life cycle. For the traffic model used, an 8 mission life cycle will be assumed.

4.3 TURNAROUND REQUIREMENTS

The turnaround requirements arise from two basic considerations; i.e., the subsystem hardware requirements (C/O, calibration, and refurbishment) and the vehicle handling and transportation requirements. From time to time there is also the requirement to modify one or more subsystems including structure, either to eliminate a marginal design or fabrication condition, eliminating a generic problem or providing increased capability. In an overall maintenance program these requirements are generally integrated in a set of scheduled (routine) and unscheduled (corrective) functional requirements and work schedule. In order to assist the user's preliminary maintenance planning efforts the following information is provided:

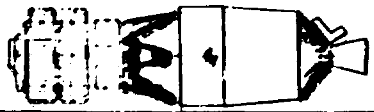
- OTV/MOTV subsystem definition and allocation chart
- Subsystem maintenance requirements
- Handling and transportation requirements
- An overall activity scenario for ground and SOC turnaround
- A typical integrated set of ground maintenance functional requirements.

4.3.1 OTV/MOTV Subsystem Allocation

Figure 4.4 identifies the various subsystems and shows the placement of the various subassemblies in the MOTV. In the displays and controls and the rendezvous radar subsystems, all the subassemblies are located in the crew capsule. For the other subsystems, percentages indicate where the subassemblies are placed. The percentages are based on the number of components or subassemblies located in each module. The location criteria, as shown, was used in determining the placement of the subassemblies.

4.3.2 Subsystem Maintenance Requirements

Tables 4.1 through 4.10 identify the primary subsystem maintenance requirements ordered per Fig. 4.3.



SUBSYSTEM	CREW CAPSULE	PROP. MODULE	DROP TANKS
DISPLAYS & CONTROLS	ALL		
DATA MANAGEMENT	TAPE RECORDER, (30%) SIGNAL CONDITIONERS BIO-MED + ECLSS SENSOR	60%	TEMP, PRESSURE (10%) SENSORS
ATTITUDE CONTROL & GUIDANCE	MANUAL NAVIGATIONAL (30%) CONTROLS, KEYBOARD COMPUTER INPUT, DIGITAL INTERFACE UNIT	70%	
TRACKING, TELEMETRY & COMMAND	CREW MICS., EARPHONES, (15%) ENCRYPTORS, DECRYPTORS	85%	
RENDEZVOUS RADAR	ALL		
EPS	CONTROLS & CKT (20%) PROTECTION	80%	
ECLSS	LIFE SUPPORT & (95%) ENVIRONMENTAL CONTROL	5% EQUIPMENT CONDITIONING	
MAIN PROP	0	2 ENGINES 100% & PROP SYS	ADDITIONAL FUEL TANKS
RCS MODULES 2267-041B	0	RCS THRUST & FEED SYS 100%	

LOCATION CRITERIA
- MAINTAINABILITY
- RELIABILITY
- WEIGHT/CG
- UNNAMED FLIGHT
- ON-ORBIT REPAIR
- DETERMINED BY USE

Fig. 4.3 OTV/MOTV Subsystems Allocation

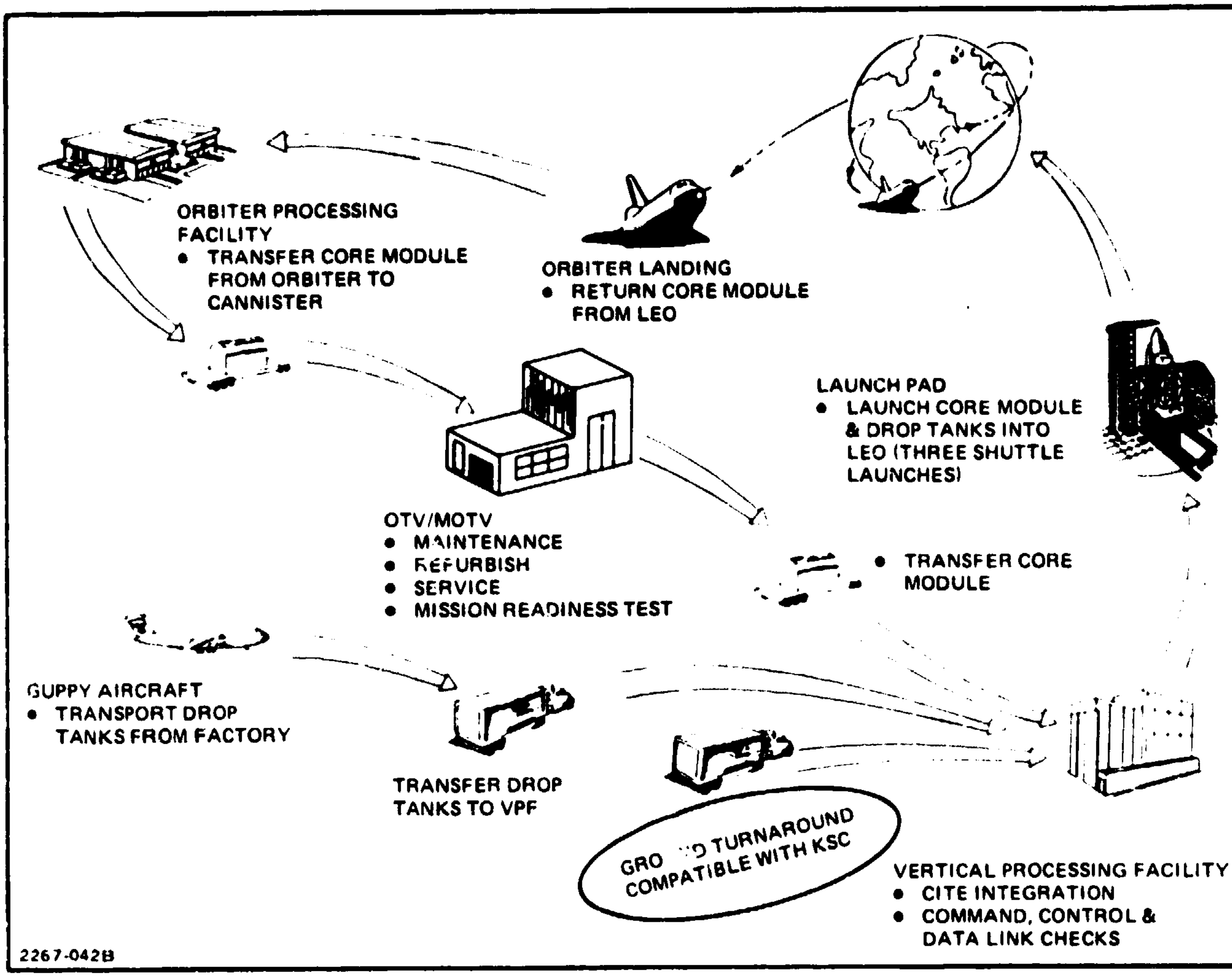


Fig. 4.4 OTV/MOTV Ground Turnaround Activity

TABLE 4.1 CREW MODULE DISPLAYS AND CONTROLS

TURNAROUND & MAINTENANCE REQ'S	POST/ PRE FLT	PERI-ODIC	FLT CRAB	OVER-HAUL	VISUAL	MANUAL	SEMI AUTO	OFI
1.0 VIDEO EQUIPMENT								
1.1 VISUAL INSPECTION	X		X	X			X	
1.2 PICTURE QUALITY TEST			X	X			X	
1.3 FUNCTIONAL TEST			X	X			X	X
2.0 COMPUTER/COMPUTER DISPLAYS								
2.1 SELF TEST		X						
2.2 COMPUTER PERFORMANCE			X	X				
2.3 CPU TIMING, REGISTER, ARITH LOGIC, INTERRUPT LOGIC, I/OC			X	X			X	X
2.4 INPUT OUTPUT CONTROLLER TRAFFIC CONTROL			X	X			X	X
2.5 MAIN MEMORY ACCESS, READ, WRITE & STORAGE			X	X			X	X
2.6 CRT PERFORMANCE			X	X			X	
3.0 CONTROLS & DISPLAYS	X							
2267-057B								

TABLE 4.2 DATA MANAGEMENT SUBSYSTEM

TURNAROUND & MAINTENANCE REQ'S	POST/ PRE FLT	PERI-ODIC	FLT CRAB	OVER-HAUL	VISUAL	MANUAL	SEMI AUTO	OFI
1.0 SENSORS								
1.1 VISUAL INSPECTION OF TEMP & PRESS. SENSORS		X	X	X	X			
1.2 CALIBRATION OF ALL SENSORS		X	X	X			X	X
2.0 SIGNAL CONDITIONING & CONVERSION								
2.1 INSPECTIONS		X	X	X	X			
2.2 SELF TEST		X	X	X			X	X
2.3 PERFORMANCE TEST			X	X			X	X
3.0 FLIGHT RECORDER								
3.1 INSPECTION		X	X	X	X			
3.2 QUALITY CHECK		X	X	X			X	
4.0 PCM ELECTRONICS								
4.1 INSPECTION	X		X	X	X			
4.2 SELF TEST		X	X	X			X	X
4.3 PERFORMANCE TESTS			X	X			X	X
2267-058B								

TABLE 4.3 ATTITUDE CONTROL AND GUIDANCE

TURNAROUND & MAINTENANCE REQ'S	POST/ PRE FLT	PERI-ODIC	FLT CRAB	OVER-HAUL	VISUAL	MANUAL	SEMI AUTO	OFI
1.0 IMU TESTS								
1.1 IMU PWR UP & PROGRAM LOAD CHECK	X		X	X			X	X
1.2 IMU CALIBRATION		X	X	X				X
1.3 ATTITUDE HOLD/POLARITY CHECK			X	X				X
1.4 IMU SELF TEST FUNCTIONAL		X	X	X				X
2.0 STAR SENSOR TESTS								
2.1 CALIBRATION			X	X				X
2.2 SELF TEST FUNCTIONAL	X		X	X				X
3.0 HORIZON SENSOR								
3.1 ATTITUDE HOLD/POLARITY CHECK			X	X				X
3.2 CALIBRATION		X						X
3.3 FUNCTIONAL			X	X				
4.0 FLIGHT RECORDER FUNCTIONAL & QUALITY CHECKS			X	X				
2267-059B								

TABLE 4.4 TRACKING, TELEMETRY, AND COMMAND

TURNAROUND & MAINTENANCE REQ'S	POST/ PRE FLT	PERI-ODIC	FLT CRAB	OVER-HAUL	VISUAL	MANUAL	SEMI AUTO	OFI
1.0 X-BAND								
1.1 INSPECT FOR DAMAGE & LOOSE PARTS	X				X			
1.2 VSWR & INSERTION LOSS CHECK			X	X			X	
1.3 XCVR PERFORMANCE VERIF		X	X	X				X
1.4 FUNCTIONAL	X						X	X
2.0 S-BAND								
2.1 INSPECT FOR DAMAGE & LOOSE PARTS	X				X			
2.2 VSWR & INSERTION LOSS CHECK			X	X				
2.3 XCVR PERFORMANCE VERIF		X	X	X				X
2.4 FUNCTIONAL	X							X
3.0 PSEUDO-RANDOM NOISE RANGING								
3.1 CALIBRATION		X	X	X				X
3.2 FUNCTIONAL	X						X	X
4.0 CABIN CONTROL CENTER								
4.1 FLIGHT RECORDER TEST			X	X				
4.2 ORB/GND LINK COMPAT TEST			X	X			X	
4.3 MOTV/EVA/ORB/GND LINK TEST			X	X			X	
4.4 SYSTEM FUNCTIONAL	X						X	
2267-060B								

TABLE 4.5 RENDEZVOUS RADAR

TURNAROUND MAINTENANCE REQ'S	POST/ PRE FLT	PERI-ODIC	FLT CRAB	OVER-HAUL	VISUAL	MANUAL	SEMI AUTO	OFI
1.0 ANTENNA SERVO								
1.1 INSPECTION	X		X	X	X			
1.2 SLEWING			X	X			X	X
2.0 TRANSMITTER & RECEIVER								
2.1 INSPECTION	X		X	X	X			
2.2 VSWR			X	X			X	X
2.3 TRANSMITTER POWER/PERFORM			X	X			X	X
2.4 RECEIVER NOISE/SENSITIVITY			X	X			X	X
2.5 TRANS & RECEIVER FREQ TESTS			X	X			X	X
3.0 RR ELECTRONICS								
3.1 INSPECTION	X		X	X	X			
3.2 RADAR RANGING			X	X			X	X
3.3 PWR SUPPLY REGULATION			X	X			X	X
3.4 OVERALL PERFORMANCE			X	X			X	X
2267-061B								

TABLE 4.6 ELECTRICAL POWER SUBSYSTEM (EPS)

TURNAROUND & MAINTENANCE REQ'S	POST/ PRE FLT	PERI-ODIC	FLT CRAB	OVER-HAUL	VISUAL	MANUAL	SEMI AUTO	OFI
1.0 SUBSYSTEM								
1.1 INSPECT COMPONENTS	X		X	X	X			
1.2 FUNCTIONAL, REDUNDANCY VERIFICATION SERVICE		X	X	X			X	X
2.0 FUEL CELL/ELECTROLYZER								
2.1 START UP & PERFORMANCE TEST		X	X	X			X	X
2.2 REACTANT & WATER CONTROLS & LEAK TEST		X	X	X		X	X	X
2.3 MECHANICAL, THERMAL INTERFACE CHECK		X	X	X	X		X	X
2.4 REPLACE FUEL CELL/ELECTROLYZER				X		X		
2.5 REPLACE REACTANT/WATER TANK				X		X		
3.0 SOLAR ARRAY								
3.1 SOLAR ARRAY DEPLOY/RETRACT & ELECTRICAL CHECK				X	X		X	
3.2 SOLAR ARRAY CONTROL & CONDITIONING CHECK			X	X			X	X
3.3 SOLAR ARRAY DRIVE/POWER TRANSFER MECH & ELECT CHECK			X	X	X		X	X
3.4 REPLACE SOLAR ARRAY		X		X		X		
4.0 BATTERY								
4.1 RECONDITIONING, ELECTRICAL PERFORMANCE TEST			X	X		X	X	X
4.2 REPLACE BATTERY		X		X		X		
5.0 POWER DIST & CONTROL								
5.1 INSPECT	X							
5.2 POWER CONTROL/ISOLATION CHECKS		X	X	X			X	X
5.3 POWER INSTRUMENTATION C/O		X	X	X			X	X
2267-062B								

TABLE 4.7 ECLS SUBSYSTEM

TURNAROUND & MAINTENANCE REQ'S	POST/PRE FLT	PERI-ODIC	FLT CRAB	OVER-HAL	VISUAL	MANUAL	SEMI AUTO	OFI
1.0 CABIN								
1.1 LEAK CHECK			X	X		X		
1.2 RELIEF VALVE FUNCT CHECK	X		X	X			X	
2.0 ATMOSPHERE REVITALIZATION SECTION								
2.1 INSPECT	X						X	X
2.2 SERVICE LIOH CANNISTERS	X						X	X
2.3 FUNCTIONAL CHECK			X	X		X		X
3.0 HEAT TRANSPORT SECTION								
3.1 PROOF – LEAK CHECK			X	X		X		
3.2 DRAIN, DRY, RECHARGE FREON				X		X		
3.3 PUMPS CHECKOUT	X					X		X
4.0 WATER RECLAMATION SECTION								
4.1 SERVICE LEAK	X					X		
4.2 FUNCTIONAL CHECK	X	X	X			X		X
4.3 POTABLE WATER TANK – FILL	X					X		X
5.0 WASTE MANAGEMENT SECTION								
5.1 SERVICE	X					X		
5.2 FUNCTIONAL CK	X		X			X		X
6.0 CREW PROVISIONS								
6.1 FOOD SERVICE	X					X		
6.2 EMU SERVICE & C.O.	X					X		
6.3 EVA SUIT C.O.	X					X		

2267-063B

TABLE 4.8 RL10 II B MAIN ENGINE

TURNAROUND & MAINTENANCE REQ'S	POST/ PRE FLT	PERI-ODIC	FLT CRAB	OVER-HAUL	VISUAL	MANUAL	SEMI AUTO	OFI
1.0 THRUST CHAMBER ASSEMBLY								
1.1 PURGE TANKS & ENGINE (H_2)	X						X	
1.2 STRUCT DAMAGE & DEFORMATION INSPECT	X	X	X	X	X	X		
1.3 LOOSE HDW, CRACKS CORROSION	X				X	X		
1.4 FUEL SYS & CHAMBER LEAK CHECKS		X	X	X			X	X
1.5 FUEL & O_2 INJECTOR FLOW CHECKS		X	X	X			X	X
2.0 EXTENDABLE NOZZLE ASSEMBLY								
2.1 THERMAL DAMAGE INSPECTIONS	X				X	X		X
2.2 PRESS DECAY LEAK CHECKS			X	X	X	X		X
2.3 FUNCTIONAL			X	X				X
3.0 TURBO PUMP & GEAR BOX ASSEMBLY								
3.1 COMPLETE INSP PARTS WEAR & SEALS		X		X	X	X		
3.2 LOOSE HDW, THERMAL DAMAGE	X				X			
3.3 INTERNAL & TURBO PUMP INTER STAGE SEAL LEAK CHECKS	X		X	X	X	X		
3.4 FUNCTIONAL – PUMP TORQUE & PERFORMANCE CHECKS		X	X	X				X
4.0 GO_2 HEAT EXCHANGER								
4.1 CRACKS, CORROSION, DAMAGE INSP		X			X			
4.2 PRESS DECAY LEAK CHECKS			X	X				
5.0 IGNITION SYSTEM								
5.1 SPARK INSPECTION	X				X			
5.2 IGNITION CONTINUITY CHECK			X	X			X	X
5.3 FUEL & O_2 FLOW CHECK			X	X			X	X
6.0 CONTROLS & INSTRUMENTATION								
6.1 LOOSE HDW & DAMAGE INSPECTION	X				X	X		
6.2 FUNCTIONAL CHECKS			X	X				X
6.3 CALIBRATIONS		X	X	X				X
7.0 ENGINE GIMBAL CONTROL								
7.1 INSPECT ACTUATOR MECHANISM	X			X	X			
7.2 FUNCTIONAL CHECK REDUNDANCY	X			X			X	X
7.3 MEASURE ACTUATION LOADS		X	X	X			X	X
8.0 ENGINE REMOVA & REPLACE				X		X		

2267-064B

TABLE 4.9 PROPULSION SYSTEM

TURNAROUND & MAINTENANCE REQT'S	POST/ PRE FLT	PERI- ODIC	FLT CRAB	OVER- HAUL	VISUAL	MANUAL	SEMI AUTO	OFI
1.0 CORE MODULE								
1.1 PURGE TANKS	X						X	
1.2 INSPECT FOR LOOSE HDW & DAMAGE	X		X	X	X			
1.3 REFURBISH FILTERS		X		X		X		
1.4 LEAK CHECKS (Q.D'S, COUPLING & VALVES)	X		X	X		X	X	
1.5 RELIEF VALVE FUNCTIONAL CHK			X	X			X	X
1.6 SYSTEM FUNCTIONAL			X	X				X
1.7 INSTRUMENTS CALIBRATION		X		X				X
2.0 TANK MODULES								
2.1 INSPECT FOR LOOSE HDW & DAMAGE	X				X			
2.2 LEAK CHECKS			X	X		X		
2.3 FUNCTIONAL CHECKS			X	X		X		X
2.4 INSTRUMENTS CALIBRATION			X	X				X
3.0 SERVICING	X						X	
2267-065B								

TABLE 4.10 ATTITUDE CONTROL PROPULSION SUBSYSTEM

TURNAROUND & MAINTENANCE REQ'S	POST/ PRE FLT	PERI- ODIC	FLT CRAB	OVER- HAUL	VISUAL	MANUAL	SEMI AUTO	OFI
1.0 LEAK & FUNCTIONAL								
1.1 PQMD CALIBRATION			X	X			X	X
1.2 REGULATOR LEAK & FUNCTIONAL			X	X			X	X
1.3 RELIEF VALVE LEAK & FUNCTIONAL			X	X			X	
1.4 CONTROL VALVES LEAK & ELECTRICAL			X	X			X	X
1.5 QUAD CHECK VALVES LEAK & FUNCTIONAL			X	X			X	
1.6 FUEL/OXIDIZER TANKS LEAK			X	X			X	X
1.7 HEATERS FUNCTIONAL			X	X			X	X
2.0 SERVICING								
2.1 PURGE & SAFE	X						X	
2.2 SERVICE FUEL	X						X	
2.3 SERVICE HELIUM	X						X	
3.0 SYSTEM END TO END LEAK TEST		X	X	X				X
4.0 INSPECTION	X							
2267-066B								

4.3.3 Handling and Transportation Requirements

Handling and transportation requirements are a function of where ground or SOC turnaround activities are accomplished and the specific tasks performed. Figures 4.4 and 4.5 addresses the handling and transportation requirements associated with overhaul of the MOTV, which take place on the ground about every eighth mission. Figures 4.6 thru 4.12 address the SOC transportation and handling requirements.

4.3.3.1 Ground Maintenance (Overhaul). Figure 4.4 illustrates the handling and transportation requirements for the MOTV activity flow at KSC. After being removed from the Orbiter in the OPF, the returning Core/Manned Module (CMM) is put in a KSC-supplied horizontal canister. The canister is routed directly to the OTV/MOTV Payload Processing Facility (PPF) for complete maintenance operations. At the PPF the crew module is demated and processed on a horizontal workstand. The propulsion core module is processed in a vertical work stand. For OTV flights the propulsion core module is taken to the VPF in a contractor supplied canister and integrated with other STS cargo in the vertical Cargo Integration Test Equipment (CITE). For MOTV flights, the crew and core module are taken separately in contractor canisters to the VPF and integrated in the vertical CITE.

Figure 4.5 discusses the handling and transportation requirements within the PPF. The OTV/MOTV configuration is removed from the Orbiter at the Orbiter Processing Facility (OPF) in the horizontal position. It is placed in the KSC standard payload canister/transporter and, if an MOTV is being processed, it is demated while in the horizontal canister. The crew module is placed in a horizontal workstand which better orients the crew compartment for maintenance purposes. The core propulsion module is placed in a vertical workstand for maintenance purposes. The core propulsio it may be necessary to recheck the drop tank-to-core interfaces which would be accomplished in the core workstand. The crew module and core modules are co-located so that a complete checkout of the MOTV functional interfaces can be accomplished with interface extender cables from the crew module. For the MOTV mission, once the maintenance phase is complete and the mission readiness test indicate both modules are "go", the modules are shipped individually on contractor provided containers to the Vertical Processing Favility (VPF). The modules would be mated and all inter-module and STS interfaces checked out in one of the VPF Cargo Integration Test Equipment (CITE) workstands. The complete vertically oriented cargo would be removed by the payload handling mechanism, put in the standard KS P/L canister and shipped to the pad. At the pad the Payload Ground Handling Mechanism (PGHM) and

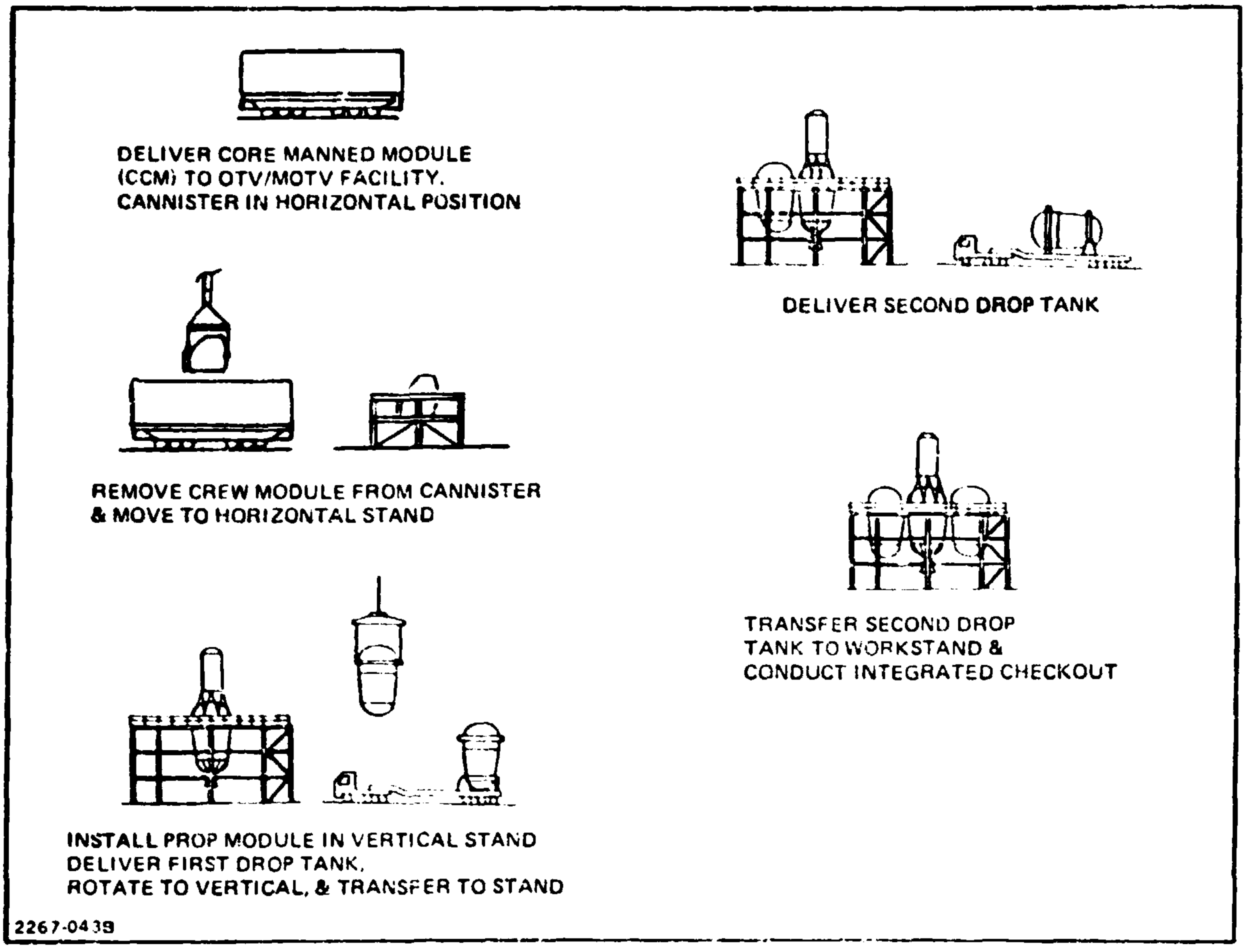


Fig. 4.5 Ground Turnaround Handling and Transportation Requirements

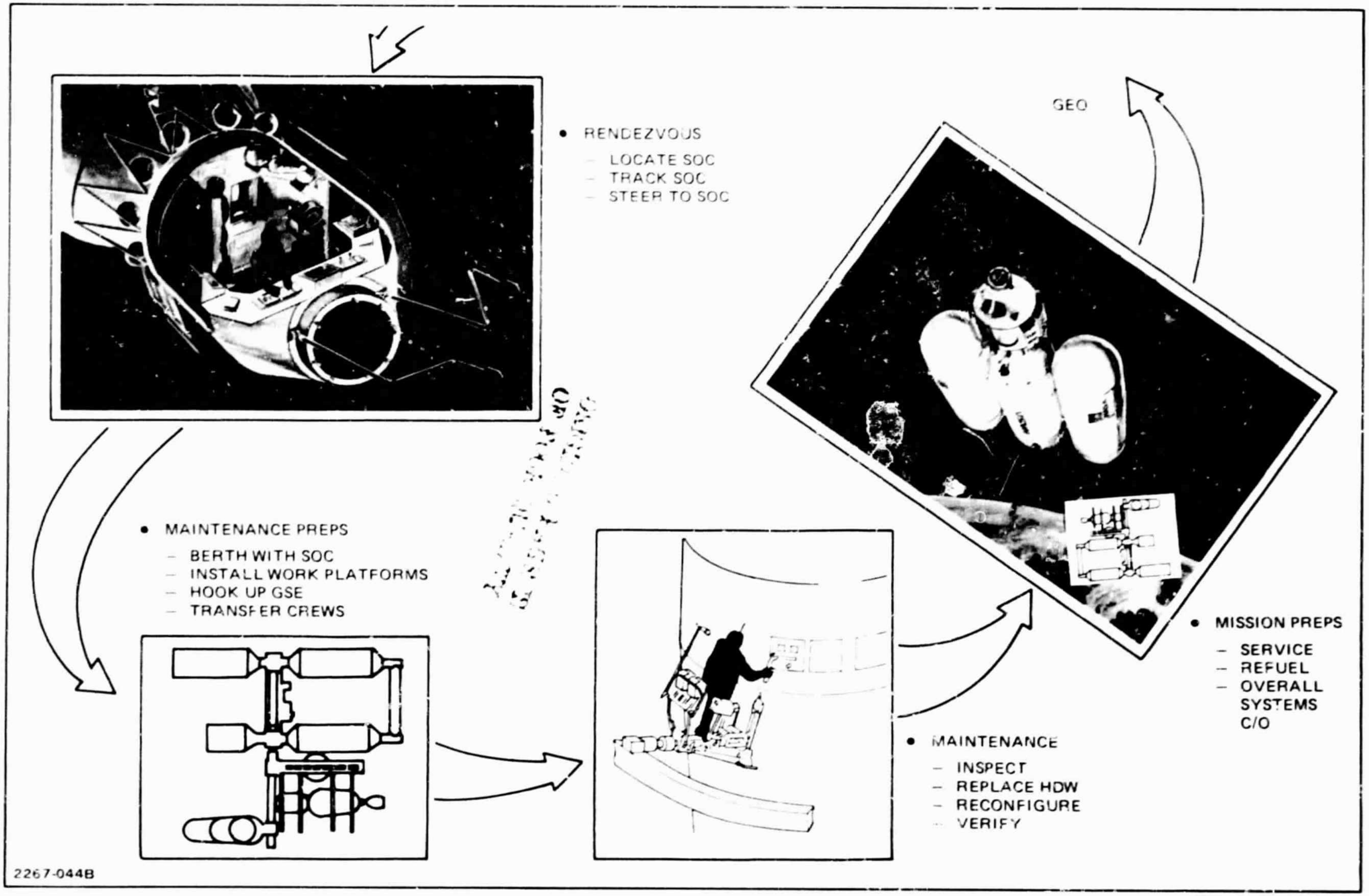


Fig. 4.6 SOC Turnaround Activity

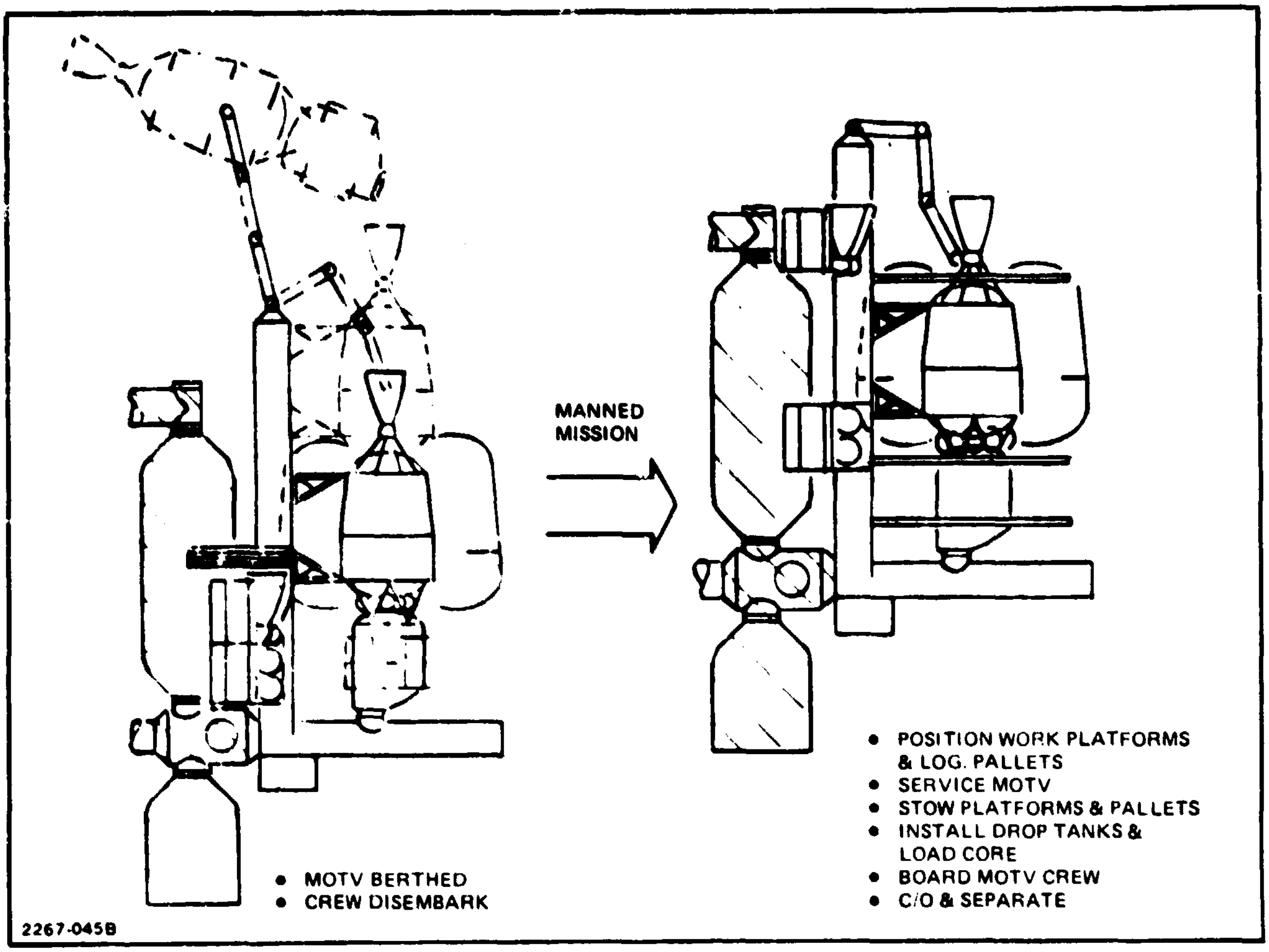


Fig. 4.7 MOTV Service Scenario at SOC – EVA Servicing (No Hangar)

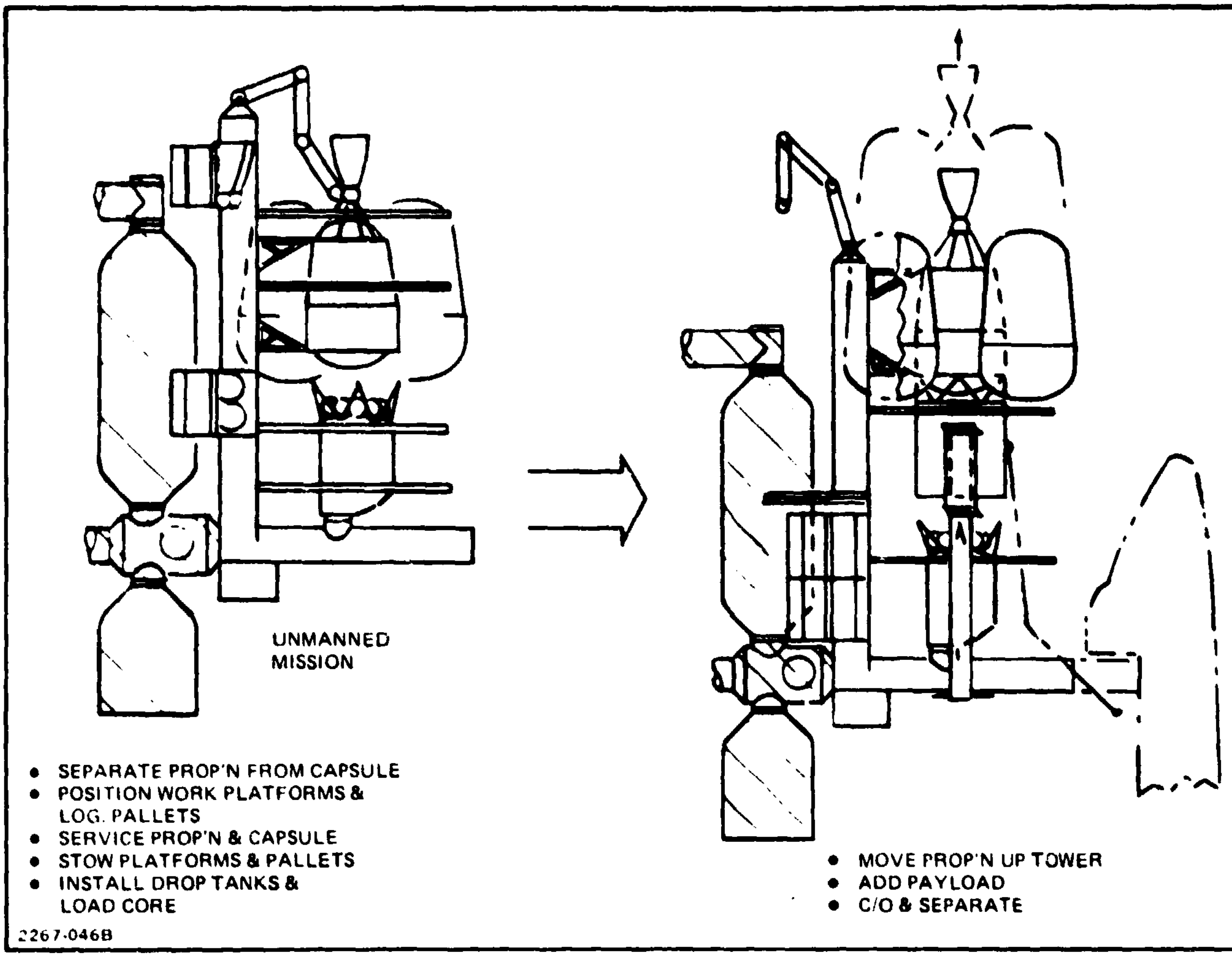


Fig. 4.8 MOTV Service Scenario at SOC – EVA Servicing (No Hangar)

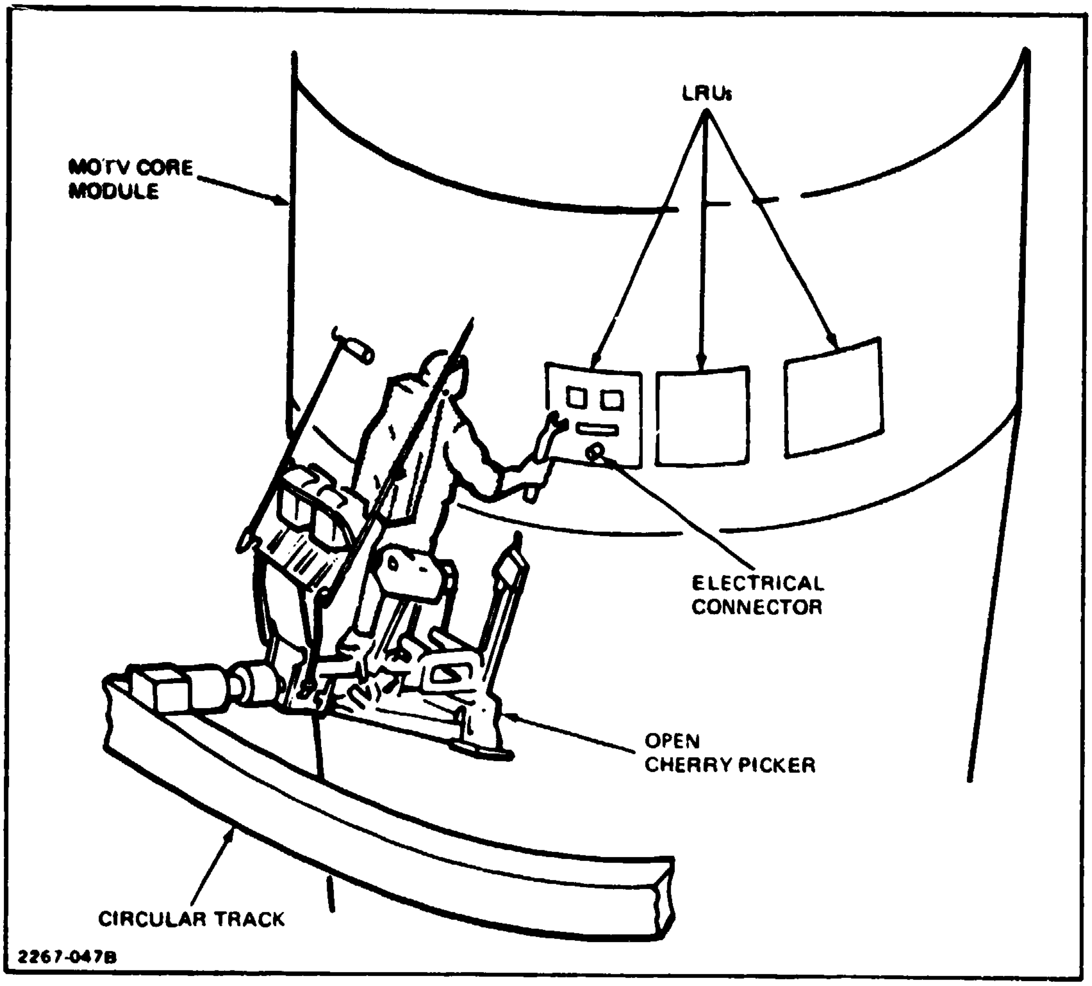


Fig. 4.9 MOTV Service Scenario at SOC-EVA Servicing (No Hangar)

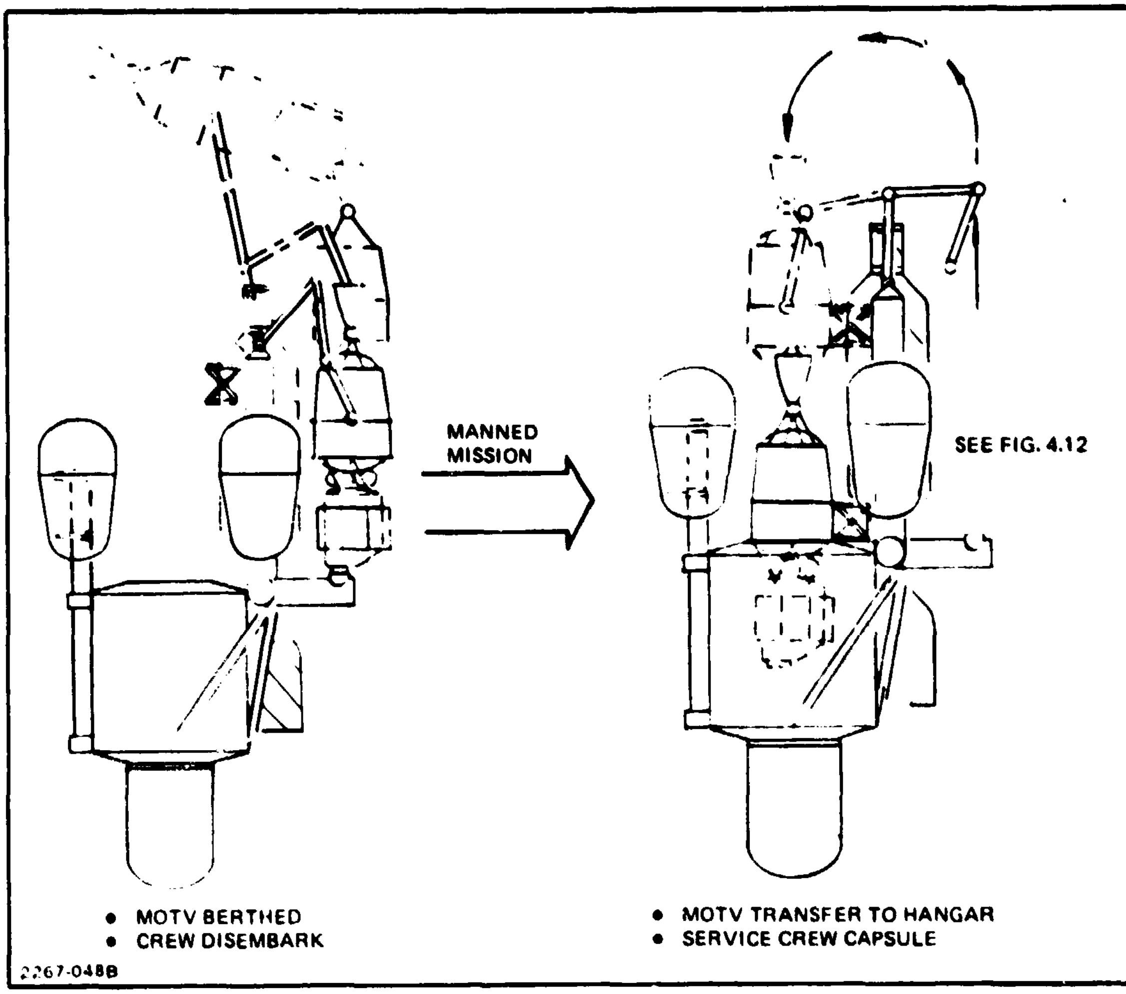


Fig. 4.10 MOTV Service Scenario at SOC – Shirtsleeve Servicing (In Hangar)

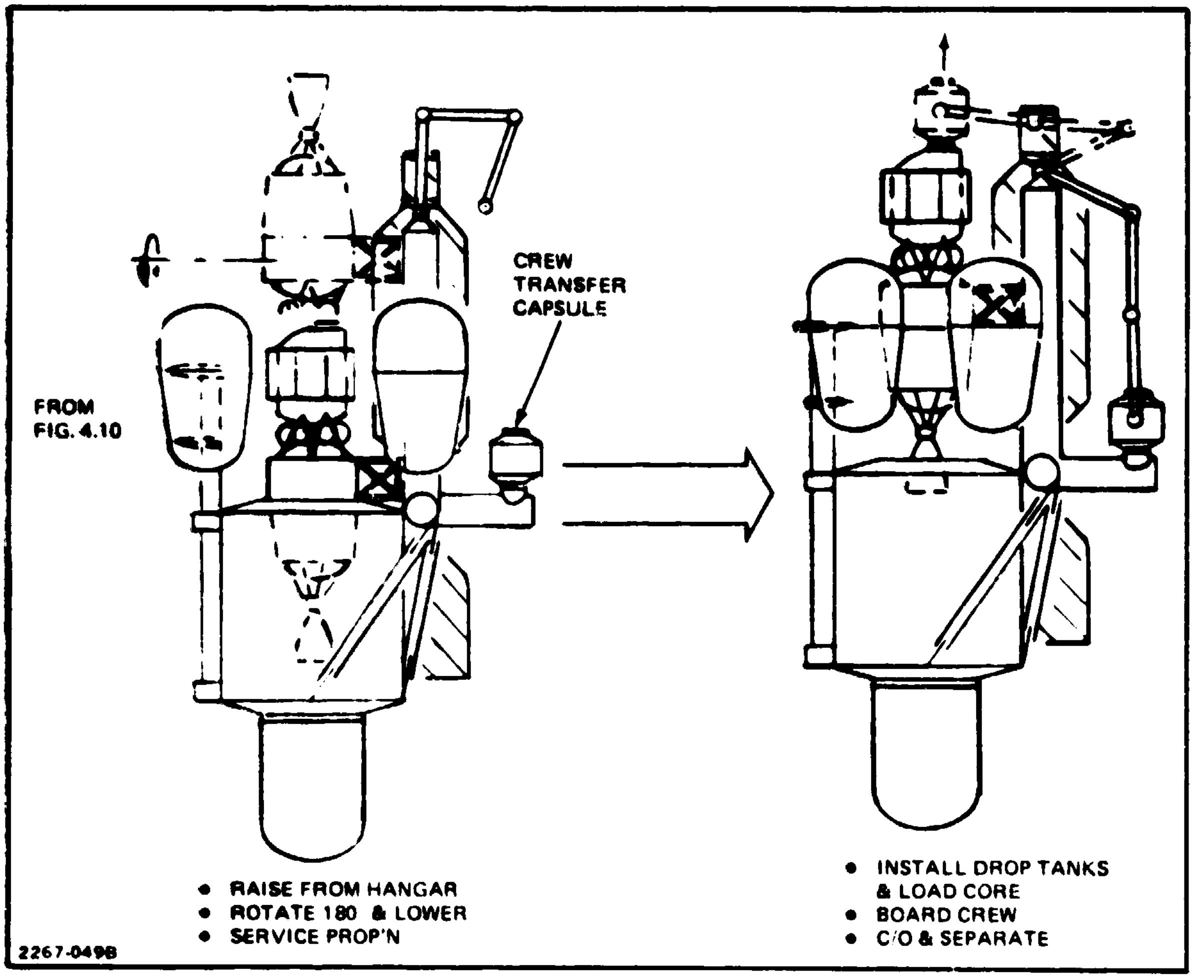


Fig. 4.11 MOTV Service Scenario at SOC – Shirtsleeve Servicing (In Hangar)

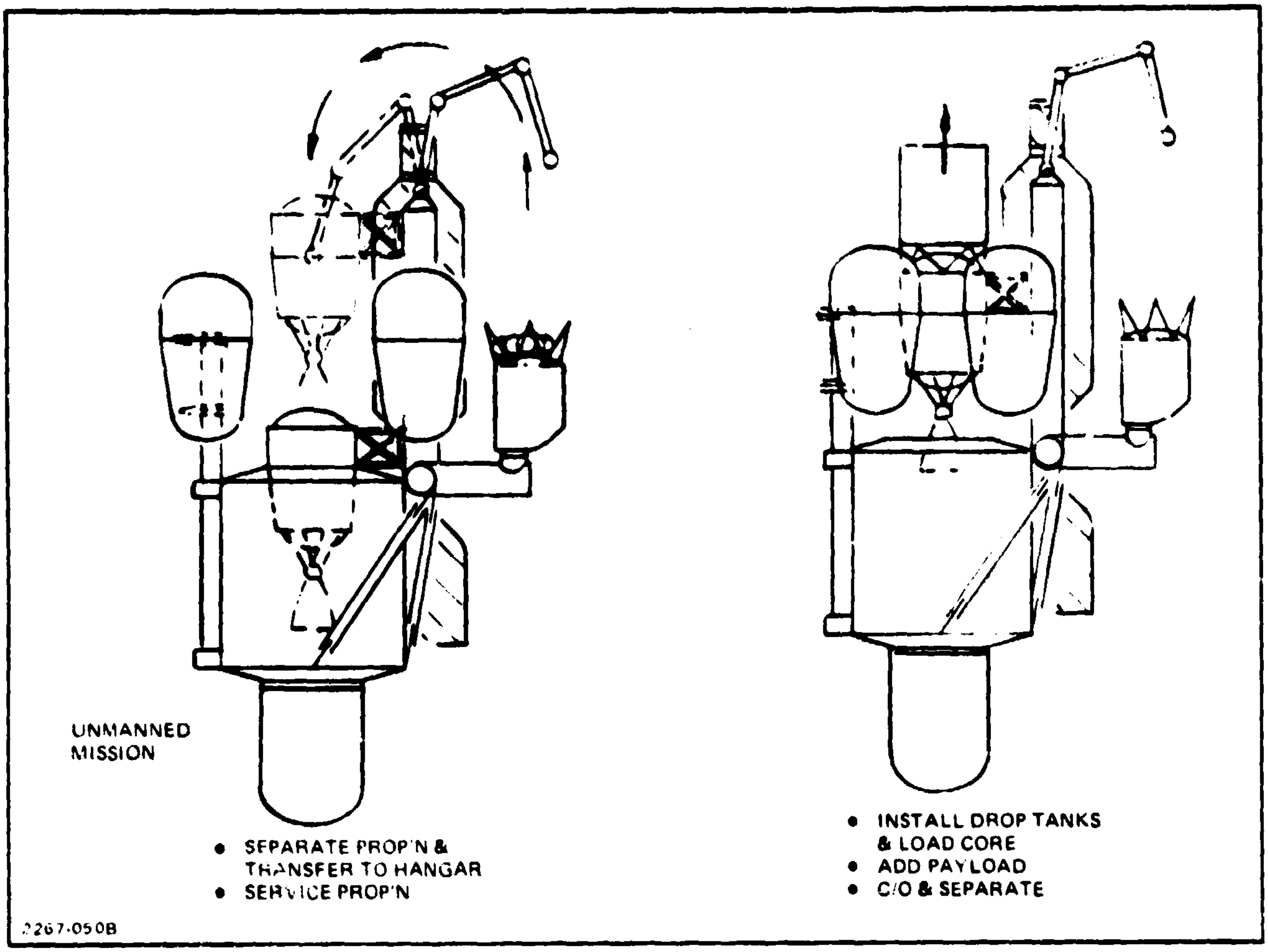


Fig. 4.12 MOTV Service Scenario at SOC — Shirtsleeve Servicing (In Hangar)

the Rotating Service Structure (RSS) would be used to service the MOTV. Fueling of the MOTV would be accomplished in parallel with the STS fueling, requiring modification to the KSC LPS controlled STS fueling system.

Drop tanks will be delivered directly to the PPF and processed for launch on the tank module work stands. They would then either go directly to the VPF for integration with the next STS flight manifest or be prepared for storage and kept in the PPF until required.

4.3.3.3 SOC Post and Periodic Maintenance. SOC handling requirements are given for the current baseline, no pressurized hangar, (Figs. 4.7, .8 and .9) and for a pressurized hangar (Figs. 4.10, .11, and .12) at SOC. The later is included because our study indicates that the hanger is a very viable operational option.

Figure 4.6 scenario shows the major activities required at LEO for SOC turnaround. Following rendezvous, the returning OTV or MOTV configuration is captured, berthed, and prepared for the required maintenance tasks. Maintenance at SOC would consist of safety and damage inspection, replacement of defective hardware (LRUs) and reconfiguring for flight. For those missions where the MOTV is returned to KSC for ground overhaul, the MOTV is captured berthed and transferred to the next Orbiter for ground maintenance, with no maintenance at SOC. Mission preparation would follow maintenance and consist of servicing the required systems, refueling and final systems check prior to GEO transfer.

Figure 4.7 proposes a scenario for servicing an MOTV at SOC with no pressurized hangar, using EVA as required. The MOTV returns from a manned flight, it is captured by a manipulator and berthed to a pressurized part of SOC for the crew to disembark. Assuming that the next mission is also manned, work platforms are positioned around the vehicle at suitable 'heights' for the EVA service crew to perform their tasks. Logistics pallets are positioned for the servicing crew to reach from their platforms. The MOTV is now serviced.

After servicing, platforms and pallets are moved out of the way, drop tanks are installed, propellant is transferred to the core. The mission crew then boards the MOTV, checks out the systems, then separates the vehicle from SOC, using the berthing manipulator.

Figure 4.8 considers EVA preparation of an OTV for an unmanned mission. This scenario starts with the return of the MOTV from a manned mission, as described on the preceding illustration. Having disembarked the crew, work platforms are positioned, propulsion core/crew capsule interfaces released, and then the core is separated from the crew capsule. Other work platforms and the logistics pallets are now positioned as required. The propulsion core is serviced and, if convenient, the crew capsule also.

After servicing, platforms and pallets are moved out of the way, drop tanks are installed, propellant is transferred to the core. If necessary, the propulsion assembly is moved again to allow installation of the payload to the forward end. To make the necessary interfaces, a work platform is positioned to support the EVA crew. The vehicle systems are checked out, then separated using the berthing manipulator to ensure no fouling of the SOC. The crew capsule may now be serviced, if it was not done so in parallel with the propulsion core.

Figure 4.9 shows the EVA astroworker in position on the open cherry picker (OCP) ready to start removal of the electrical connectors using the special connector tool. The OCP is mounted on the service tower platform rail which has been positioned to facilitate the replacement task. The LRU is a multi-mission communications-band transmitter module which is designed for SOC replacement.

Figures 4.10 and .11 assume that a pressurized hangar is available and propose a scenario for servicing an MOTV at SOC, using unsuited crewman working in a pressurized atmosphere. The MOTV returns from a manned flight, is captured by a manipulator, and berthed to a pressurized part of SOC for the crew to disembark. Assuming that the next mission is also manned, the manipulator transfers the vehicle to a pressurizable hangar which accepts the crew capsule and its appendages. These are now serviced from work platforms in the hangar.

Referring to the following illustration (Sheet 2), the vehicle is raised from the hangar, rotated through 180° then lowered back into the hangar so that the propulsion subsystem concerned with the engines, and the subsystems located between the propellant tanks, are contained within the hanger. These subsystems are now serviced. On completion, the vehicle is again raised from the hangar, drop tanks are installed and propellant is transferred to the core. As presently envisaged, the MOTV crew boards a small capsule which is transferred by the manipulator to berth with the MOTV crew capsule. The crew then board the MOTV. The transfer capsule is removed, the vehicle systems checked out, then separated from SOC using the berthing manipulator to avoid possible fouling of SOC.

Figure 4.12 considers preparation of an OTV for an unmanned mission, using shirtsleeved crewmen working in a hanger at SOC, this scenario starts with the return of an MOTV from a manned mission, as described on a preceding illustration. Having disembarked the crew, propulsion core/crew capsule interfaces are released; then the core is transferred by the manipulator to be lowered into the pressurized hangar, engines first. As with the preceding scenario, propulsion subsystems are serviced. The propulsion core is now raised out of the hangar, drop tanks are installed using the manipulator, with perhaps some EVA assistance and, in the same manner, the payload is installed.

After checkout, the vehicle is separated from SOC by the berthing manipulator.

4.3.4 Integrated Functional Requirements

The functional requirements discussed in this paragraph satisfy the subsystem, handling and transportation requirements discussed in paragraph 4.3.2 and 4.3.3 respectively. Table 4.11 integrates these functional requirements for the ground overhaul maintenance activities from post landing to launch. It assumes the refurbished and serviced core/crew module configuration will be returned to SOC where the configuration will be tailored for the next flight, including the installation of mission peculiar equipment. Table 4.11 includes the operations required in the OPF, the PPF and VPF as well as transportation to these facilities and the launch pad. It includes the ordered functional requirements at each location, a time estimate and identification of support required.

Table 4.12 provides an integrated set of functional requirements for SOC periodic maintenance with a list or facility of any special MOTV interface requirements to adapt it for the SOC maintenance function.

4.4 TURNAROUND SUPPORT REQUIREMENTS

The following paragraphs discuss the preliminary baseline estimate of facility, hardware and personnel required to support the functional requirements discussed in paragraph 4.3.

TABLE 4.11 OTV/MOTV INTEGRATED FUNCTIONAL REQUIREMENTS – GROUND OVERHAUL OPERATIONS (SHEET 1 OF 4)

TASK NO.	LOCATION	FUNCTIONAL REQM'T	TIME, HR	SOFTWARE	EQUIPT	REMARKS
1.0	LANDING AREA	NONE	–	–	–	FINAL MOTV C/O PRIOR TO LNDG. REMOVE FLT OR-BITER EQUIPT & TASK
2.0	ORBITER	INSTALL P/L ACCESS PLATFORMS CORE/MAN MODULE (CMM) PRELIM INSPECTION	1	NONE	WK PLATFORMS	
2.1	PROCESSING					
2.2	FACILITY	ATTACH HANDLING SLING & STRONG BACK	1.5		SLINGS & STRONGBACK	STRONG BACK STD ORBITER EQUIP
2.3	OPF	INSTALL CMM IN HORI-ZONTAL CANNISTER	2.0			
2.4		INSTALL CANNISTER ON XPORTER	2.1			
2.5		XPORT TO PPF	4			
3.0		POSITION CANNINSTER, & DECOUPLER CREW & PROP MODULES	1.5		HOLDING FIX & OVERHEAD CRANE	
3.1	OTV/MOTV	INSTALL EACH MODULE ON RESPECTIVE WK STANDS	1.0			
3.2	PAYLOAD PROCESSING FACILITY	POSITION WK PLATFORMS, HOOK UP GSE & ESTABLISH CONDITIONING	1.0	NONE	WK PLATFORMS FLUID & ELECTRICAL GSE PLUGS LPS INTERFACE UNITS	
3.3		POST FLT SAFETY & DAMAGE INSP	2.0			
3.4	(MOTV PPF)	REMOVE ACCESS DOORS	2.0			
	CREW MODULE AND PROP MODULE BOTH READY FOR MAINTENANCE					
4.0		SCHEDULED MAIN-TENANCE				
4.1	MOTV PPR INDIVIDUAL WORK STANDS	VISUAL INSPECTIONS STRUCT/TANK SUP-PORTS, DOCKING MECH, AVIONICS COMPONENTS & CONTR'LS SOLAR AR-RAY & EPS, RR, COMM & TELEMETRY ANTEN-NAS; MAIN ENGINE NOZZLE & TURBINE COMPONENTS FLUID LINES, ECLSS PLUMB-ING & COMPONENTS, ALL ORBITER P/L BAY INTERFACES, RADIA-TION PROTECTION TILES, PROTECTIVE COVERS, SELECTED STRUCT/MECH COM-PONENTS FOR EVI-DENCE OF PHYSICAL WEAR, RADIATOR PANELS, FLT CNTRL THRUSTERS	10			

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TABLE 4.11 OTV/MOTV INTEGRATED FUNCTIONAL REQUIREMENTS – GROUND OVERHAUL OPERATIONS (SHEET 2 OF 4)

TASK NO.	LOCATION	FUNCTIONAL REQM'T	TIME, HR	SOFTWARE	EQUIPT	REMARKS
4.2		REMOVAL & REPLACEMENT OF TIME LIMIT & EXPENDABLES FUEL, & H_2O FILTERS; SELECTED RCS, ENGINE & FUEL CELL COMPONENTS; SOLAR ARRAY & BATTERIES; IMU, SENSORS & POTS REQUIRING BENCH CALIBRATION	12			WORK ON MODULES PERFORMED IN PARALLEL
4.3	MOTV INDIVDUAL WK STANDS	END TO END LEAK CHECKS, RELIEF VALVE & REDUNDANT VALVE CHECKS OF PROP. ATTITUDE CNTRL, ECLSS, EPS	8	CNTRL & C/O ROUTINES		TO BE ACCOMPLISHED FLOWING SCHED & UNSCHEDULED COMPONENT REPLACEMENT
4.4		COMPLETE FUNCTIONAL END TO END POST MAINTENANCE C/O: EPS PWR UP, COMPUTER SELF CHECK, CONTROLS & DISPLAYS, PWR SWITCH OVER ECLSS FUNCTIONALS, COMM & INTER COMM FUNCT., IMU SELF & POLARITY TESTS, HORIZON & STAR SENSOR FUNCTIONA RR FUNCTIONAL LOAD & CHECK MISSION SOFTWARE & MISSION SIM INCLUDING MAIN ENGINE GIMBALING & RCS SIM. FIRING	10	C/O & CONTROL SOFTWARE	FLUID ELECTRICAL GSE INCLUDING ANTENNA HATS, HARDLINE BETWEEN STANDS & LPS INTERFACE	CONDUCTED WITH LPS & GROUND COMPUTER TO BE ACCOMPLISHED AT END OF SCHED & UNSCHEDULED MAINTENANCE
5.0	UNSCHEDULED MAINTENANCE TYPICAL ITEMS					TOTAL OF 48 HR ALLOTED FOR UNSCHEDULED MAINTENANCE
5.1	HOT INDIVIDUAL WK STANDS	NON DESTRUCTIVE TESTS & REPAIR OF STRUCTURE, TANKS, THERMAL BLANKETS, MECH COMPONENTS	24	C/O, CONTROL & DIAGNOSTIC ROUTINES	FLUID ELECTRICAL GSE INCLUDING ANTENNA HATS, HARDLINE BETWEEN STANDS & LPS INTERFACE	
5.2		DIAGNOSTIC TESTING TO VERIFY & ISOLATE ANOMALIES	8			
5.3		REMOVE & REPLACE LRU'S SECONDARY STRUCTURE OR FLUID LINES	8			
5.4		FURTHER INSPECTION OF SUSPECT AREAS REQUIREING PARTIAL DISASSEMBLY OF EQUIPMENT OR STRUCTURE	4			
5.5		REMOVAL & REPLACEMENT OF MAJOR ASSEMBLY FOR OVERHAUL	4			
5.6		RECONFIGURE BOTH MODULES & SECURE FROM MAINT OPS	8			
MAINTENANCE OPERATIONS COMPLETE						

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TABLE 4.11 OTV/MOTV INTEGRATED FUNCTIONAL REQUIREMENTS – GROUND OVERHAUL OPERATIONS (SHEET 3 OF 4)

TASK NO.	LOCATION	FUNCTIONAL REQM'T	TIME, HR	SOFTWARE	EQUIPT	REMARKS
6.0		PREP FOR MOVE				
6.1		CLEAN CABIN & CORE EXTERIOR	6			
6.2		POWER DOWN & SECURE ALL SYSTEMS	2	NONE		
6.3		LOAD MISSION KITS & CLOSE OUT CABIN	8			
6.4	MOTV	DISCONNECT & REMOVE GSE	2			
6.5	INDIVIDUAL WK STANDS	REMOVE WORK PLATFORMS	1.5			
6.6		XFER MODULES TO INDIVIDUAL CANNISTERS	1.5		CANISTERS	
6.7		INSTALL ON XPORTERS	1.5			
6.8		XPORT TO VPF	4			
7.0		VPF INTEGRATION				
7.1		CLEAN CANNISTER @ VPF AIR LOCK	4			
7.2		POSITION CANNISTER & INSTALL CORE MODULE IN CITE & SECURE	1.5			
7.3		POSITION CANNISTER & INSTALL CREW MODULE IN CITE & SECURE	1.5			
7.4		MATE & CHECK MODULE INTERFACES	1.5			
7.5	VERTICAL	CONNECT ALL FLUID & ELECTRICAL GSE & CITE INTERFACE LINES	1.5			
7.6		CONDUCT MISSION READINESS TEST TO C/O ALL ORBITER INTERFACES INCLUDING DATA LINKS	2	C/O & SOFTWARE & INTEGRATED ORBITER TEST ROUTINE		
7.7	PROCESSING	PWR DOWN, DISCONNECT GSE & CITE INTERFACES	1.0			
7.8	FACILITY	COMPLETE CABIN STOWAGE OF CONSUMABLES	2			
	VPF	CLOSE OUT CABIN & RETRACT MOVABLE WK PLATFORMS	1			
7.9		POSITION CANNISTER BY CITE & XFER CREW/CORE MODULE TO VERTICAL CANNISTER	1.5		KSC CANNISTER	MULTI MISSION EQUIPMENT
7.10		XPORT TO PAD	8			
7.11		INSERT IN RSS & PREP FOR ARRIVAL OF STS	16			

2267-0678(3)

TABLE 4.11 OTV/MOTV INTEGRATED FUNCTIONAL REQUIREMENTS – GROUND OVERHAUL OPERATIONS (SHEET 4 OF 4)

TASK NO.	LOCATION	FUNCTIONAL REQM'T	TIME, HR	SOFTWARE	EQUIPT	REMARKS
8.0	LAUNCH PAD	FINAL PAD OPERATIONS	7.5	INTEGRATED ORBITER		
8.1		INSTALL & INTEGRATE P/L IN ORBITER (INCLUDING ORBITER COMPATIBILITY CHECKS)	7.5	TEST ROUTINE	PGHM	
8.2		REFUSE CORE	2 HRS	AUTOMATIC FUELING ROUTINE		KSC FACILITY SYSTEM USED

2267-067B(4)

TABLE 4.12 SOC TURNAROUND SUPPORT REQUIREMENTS FOR MOTV CREW & PROP CORE (SHEET 1 OF 3)

ACTIVITY	FUNCTIONAL REQUIREMENT	FACILITY REQ'MTS	SUPPORT EQUIPT REQD	SOC MOTV DESIGN IMPACT
1.0 RENDEZVOUS	1.1 LOCATE, IDENTIFY, & TRACK A COOPERATIVE OR PASSIVE MOTV	SHIRT SLEEVE (SS) CNTRL ROOM ≈ 240 SQ FT	BEACON XPONDER, REND RADAR, DISPLAYS	NON – STD RENDEXVOUS EQUIP ON BOARD
	1.2 BERTH COOPERATIVE OR PASSIVE MOTV TO SOC & SECURE	BERTHING/DOCKING INDEXED TURNTABLE, WITH CLEAR APPROACH	BERTHING RING & GRAPPLER	NONE – STD BERTHING/DOCKING RING WITH GRAPPLER
2.0 MAINTENANCE PREPS	2.1 TRANSFER CREWS AND DEBRIEF	SS DEBRIEFING AND MAINT PLANNING AREA ≈ 400 SQ FT	VIDEO, DATA & VOICE TRANSMISSION SYSTEM	NONE – INDEPENDENT SOC FUNCTION
	2.2 INSTALL & SECURE WORK PLATFORMS @ CREW & PROP MODULE LEVELS	MAINT/SERVICE FACILITY WITH MOVABLE WK PLATFORMS	NONE WORK PLATFORMS PART OF FACILITY	NONE
	2.3 REMOVE ACCESS PANELS	NONE –	SPECIAL TOOLS INCLUDING OCP	ACCESS PANEL FASTENERS DESIGNED FOR SPACE REMOVAL, PANELS & FASTENERS INCORPORATE TETHER PROVISIONS
	2.4 INSTALL PWR, FLUID SERVICE LINES AND SOC SUPPORT EQUIPT (SSE)	• PWR, SERVICE & SUPT EQUIP FLEX LINES WITH QUICK DISCONNECTS • EQUIPMENT IN SS AREA	FLUID SERVICING SUPPORT EQUIPMENT, AVIONICS SUPPORT EQUIPMENT	NONE – QUICK DISCONNECT PORTS SAME AS FOR GND SERVICING
3.0 SCHEDULED MAINTENANCE	3.1 REMOVE FLIGHT DATA RECORDER TAPES & TRANSMIT TO GROUND MOTV MAINT CNTRL	COMMUNICATIONS FACILITY GND, TDRS, SATELLITES, GPS CAPABILITY (VOICE & DATA)	TDRS/GND COMM EQUIPMENT WITH MINI COMPUTER, PLAYBACK & PRINTOUT EQUIPMENT	NONE – SOC FUNCTION
	3.2 SAFETY & DAMAGE INSPECTIONS – PER FLIGHT INSPECTION OF MOTV – STRUCTURE: CONCENTRATED LOAD POINTS, OUTER SHELLS, STRUTS, & SUPPORTS FOR CRACKS OR DAMAGE – ENGINE: OVERALL, THRUST CHAMBER, IGNITER, ENGINE ACTUATOR MECHANISM & ATTACHMENTS, EXTENDABLE NOZZLE, ACCESSIBLE SEALS, BORESCOPE TURBO GEARS & BEARINGS – PROPULSION SYS: ALL COMPONENTS FOR SECURITY & CONDITION – RCS: THRUSTERS, TNKS & PLUMBING – AVIONICS: ALL COMPONENTS INCLUDING ANTENNAS FOR SECURITY & CONDITION – EPS: DISTRIBUTION, BATTERIES, FUEL CELLS, SOLAR ARRAYS – ECLSS: ALL CABIN & EXTERNAL COMPONENTS	EVA MAINT FACILITY WITH APPROPRIATE LIGHTING, WK PLTFORMS, AND MAINTENANCE SERVICES	INSPECTION TOOLS INCLUDING ENGINE & THRUSTER BORESCOPES, TV & PHOTOGRAPHY EQUIPMENT TO MAP CRITICAL AREAS AND RECORD AND TRANSMIT TO GND QUESTIONABLE AREAS	MOTV DESIGN MUST PROVIDE INSPECTION ACCESS TO PLUMBING AND CRITICAL COMPONENTS SUCH AS ENGINE THRUST CHAMBER, IGNITER & ENGINE GIMBAL ACTUATOR, EPS BATTERIES, FUEL CELLS AND CKPT PROTECTION DEVICES ETC

2267-068B(1)

TABLE 4.12 SOC TURNAROUND SUPPORT REQUIREMENTS FOR MOTV CREW & PROP CORE (SHEET 3 OF 3)

ACTIVITY	FUNCTIONAL REQUIREMENTS	FACILITY REQ'MTS	SUPPORT EQUIPT REQD	SOC MOTV DESIGN IMPACT
6.0 MOTV TANK ASSEMBLY	6.1 PREP DROP TANKS & SWING INTO POSITION 6.2 POSITION DROP, MECHANICALLY ENGAGE 6.3 CONNECT FLUID & ELEC LINES & C/O INTERFACE 6.4 INDEX MOTV CORE TO ACCEPT NEXT TANK	SAME MAINTENANCE FACILITY WITH CRANE CAPABLE OF REACHING STORAGE TANKS, MOTV BERTHING FIXTURE CAPABLE OF INDEXING FOR MULTIPLE TANKS & OCP FOR CONNECTING & INSPECTION	NONE-COVERED BY FACILITY	NO IMPACT BASIC DESIGN MUST PROVIDE FOR ASS'LY IN SPACE
7.0 FINAL MISSION PREPS	7.1 FINAL STOWAGE OF CONSUMABLES 7.2 CLOSEOUT INSPECTION 7.3 XFER CREW, ACTIVATE MOTV, FINAL PRE IGNITION C/O & SEPARATE	NONE	NONE	NONE
8.0 DEMATE & MATE MOTV	8.1 ENGAGE PROP CORE MODULE HOLDING FIXTURE 8.2 DISCONNECT LINES & MECHANICAL LATCHES 8.3 MOVE PROP CORE TO ITS WORK STATION 8.4 FOR MATING PREP BOTH MODULES – MOVE PROP MODULE INTO POSITION – CONNECT LINES & MECHANICAL LATCHES – INSPECT & C/O INTERFACE	MAINT. FACILITY MUST HAVE • A CREW MODULE WK STATION • A CORE MODULE WK STATION • MOTV WK STATION • APPROPRIATE HOLDING FIXTURES FOR ABOVE	MATE, DEMATE TOOLS	DESIGNED TO FACILITATE SOC MATE & DEMATE
9.0 GENERAL	9.1 CORE & PROP MODULES BROUGHT FROM STORAGE TO WORK STATIONS 9.2 DETERMINE HEALTH, STATUS & SUSPECT LRU	MAINT FACILITY CRANE MUST BE ABLE TO REACH STORED PROP CORE MODULE & STORED CREW MODULE AS WELL AS STORED TANKS	NONE	ON BOARD INSTRUMENTATION (OBI) TO PROVIDE HEALTH & STATUS OF ALL EQUIPMENT & IDENTIFY SUSPECT LRU

2267-068B(3)

TABLE 4.12 SOC TURNAROUND SUPPORT REQUIREMENTS FOR MOTV CREW & PROP CORE (SHEET 2 OF 3)

ACTIVITY	FUNCTIONAL REQUIREMENT	FACILITY REQ'MTS	SUPPORT EQUIPT REQD	SOC MOTV DESIGN IMPACT
3.0 SCHEDULED MAINTENANCE	3.3 PLANNED REPLACEMENTS – PER FLT RCS HYDRAZINE (MMH) FUEL TANKS, LITHIUM HYDROXIDE FILTERS, EPS BATTERIES – PERIODIC: RCS THRUSTER MODULES, H_2O FILTERS, TV LAMPS, SOLAR PANELS	LOGISTICS AREA FOR LRU, SUPPORT EQUIPMENT & MATERIAL STORAGE ~ 5000 SQ FT & TBD PWR	OCP & SPECIAL TOOLS FOR LRU REPLACEMENTS, SOLAR PANELS & MISSION EQUIPMENT	ALL REPLACEABLE UNITS DESIGN'D AS SPACE REPLACEABLE LRU'S WITH SPECIAL FEATURES FOR ALIGNMENT, ATTACHMENT, & TETHER OF LOOSE PARTS
	3.4 SERVICE SYSTEMS: WASTE MGT, H_2O, ECLSS O_2 & N_2 TNKS, FUEL CELL O_2 & H_2 TNKS, EVA SUITS, CREW CONSUMABLES, INSTALL MISSION HRDWARE, LOAD & UPDATE NAVIGATION AND MISSION SOFTWARE	SERVICE EQUIPT FLUID, ELECTRICAL & CNTR'L LINES	SERVICE UNITS FOR GOX GN_2, H_2O & WASTE MGT & FUEL CELLS	SPACE DESIGNED EXTERNAL INTERFACE ADAPTERS FOR SERVICE
	3.5 POST MAINT C/O: PER FLT CONDUCT OVERALL MISSION SIMULATION READINESS TEST TO C/O MISSION S.W./HDWRE INTEGRATION AND SUPPORTING SYSTEMS. PERIODIC (3 FLTS) ENGINE & PROP SYSTEMS OVERALL LEAK & FUNCTIONALS, TURBO PUMP & TURBINE TORQUE CHKS, GIMBAL ACTUATOR LOAD CHECKS, ECLSS & NAVIGATION SYS C/O	SUPPORT EQUIPT INTERFACING CABLES & LINES WITH VEHICLE	CABIN AIR SUPPLY, COOLING, ECLSS C/O, HELIUM PRESS UNIT, PURGE & DRY UNIT, ENGINE THROAT PLUGS & PROP C/O UNIT, TORQUE WRENCHES, INSTRV & NAVIG STIMULI & C/O EQUIPMENT	SPACE DESIGNED EXTERNAL INTERFACE ADAPTERS FOR C/O UNITS
4.0 UNSCHEDULED MAINTENANCE	4.1 INSPECTION OF SUSPECT AREAS 4.2 REPLACEMENT OF SUSPECT LRU'S 4.3 SIMPLE STRUCTURE, THERMAL & RADIATION PROTECT REPAIR 4.4 ACCOMPLISH MINOR MODS	SAME AS CALLED OUT FOR 3.0	SAME REQMTS AS FOR 3.0 PLUS HAND TOOLS FOR REPAIR & MODS	SAME AS ABOVE PLUS MINOR MOD KITS DESIGNED FOR SPACE INSTALLATION
5.0 REFUEL CORE PROP MODULE	5.1 VENT, CHILLDOWN & FILL LH_2 5.2 VENT, CHILLDOWN & FILL LO_2	SS REFUELING CNTRL ROOM WITH AUTOMATIC FUEL TRANSFER EQUIPMENT FOR XFER FROM SHUTTLE OR SOC FUEL TANKS TO PROPULSION CORE	FACILITY INCLUDES PUMPING EQUIPMENT, CONTROLS AND DISPLAYS	NO IMPACT SAME AS GROUND FUELING

2267-068B(2)

4.4.1 Facilities Baseline Requirements

Figure 4.13 is a layout of the type of OTV/MOTV processing facility required at KSC. It would contain a 60 ft. high bay area with a 100,000 cleanliness level. The high bay would have two adjacent work stands (one horizontal and one vertical), an air lock for receiving and cleaning the cannisters prior to bringing them into the work area, and room to store movable work platform, drop tanks, mission equipment and transportation cannisters. Also included are two additional work stands which can be used for either propulsion core or drop tank module maintenance. The low bay area provides equipment and logistics stowage and shop and office space. This type of facility would be used for overhaul, any contingency or modification work on the OTV and MOTV configurations. It is intended as preliminary baseline information which would be refined as the design and traffic information matures. When facility requirements are refined, a trade should be accomplished to determine whether existing KSC facilities can meet the requirements and can be dedicated to the OTV/MOTV program.

The artist's concept (Fig. 4.14) and sketches (Figs. 4.15 and .16) illustrate typical concepts for a SOC OTV/MOTV turnaround facility. They were developed as an aid in determining how various tasks might be accomplished at SOC and are offered for information only. Current SOC studies underway should establish further facility requirements and concepts.

Figure 4.14 is an artist's rendering of what a SOC MOTV turnaround facility might look like. It would include work platforms, berthing capability, logistics modules and drop tank plus crew/core modules work stands.

To perform the tasks identified in the paragraph 4-4, MOTV servicing scenarios, Fig. 4.15 shows a facility where the turnaround crew work EVA. The basic SOC is shown 'cross-hatched' to emphasize the added facilities. The tunnel to which the Orbiter docks on the standard SOC layout has been extended. A service tower has been added, attached to the tunnel, and running parallel to SOC habitation modules. This service tower has a series of tracks over its length along which carriages run to support the MOTV and position it where required, logistics pallets, and a series of work platforms which can be closed to surround the MOTV at appropriate levels. Each work platform has a travelling stand on which the EVA man moves around the workpiece. A crane mounts to the top of the tower, where it operates to berth the MOTV to the carriages and to provide the muscle to transfer components, such as engines, from logistics pallets to installation site. Outrigger structures from the tunnel support pylons which mount drop tanks on swing arms. The tanks can be brought up by

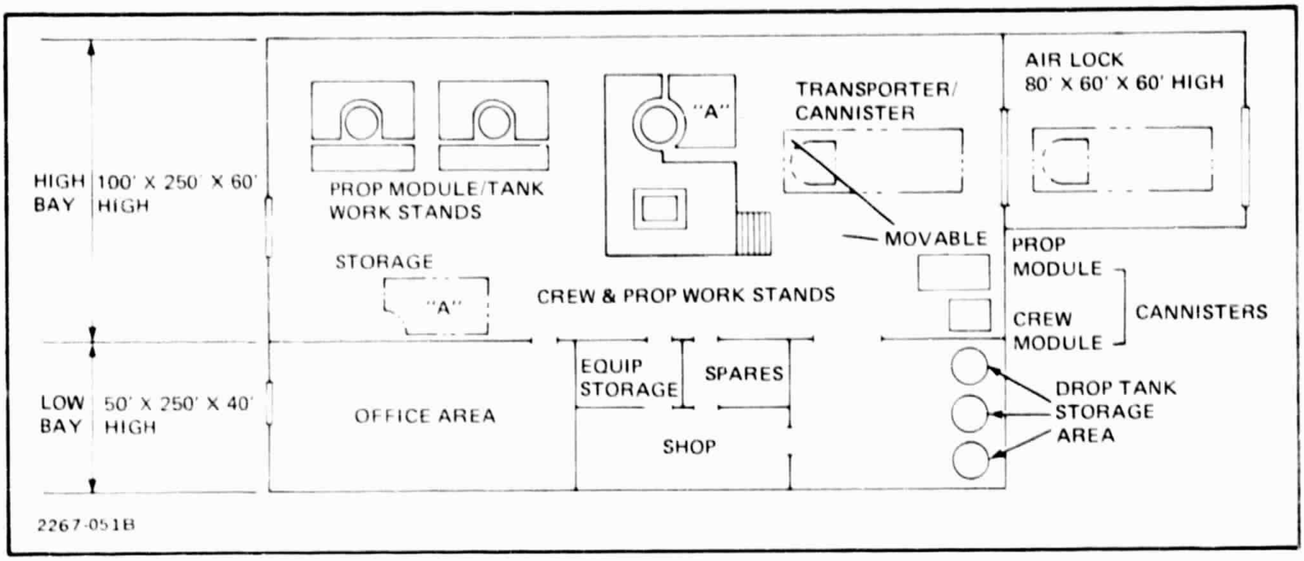

Fig. 4.13 OTV/MOTV Ground Maintenance C/O and Integration Facility

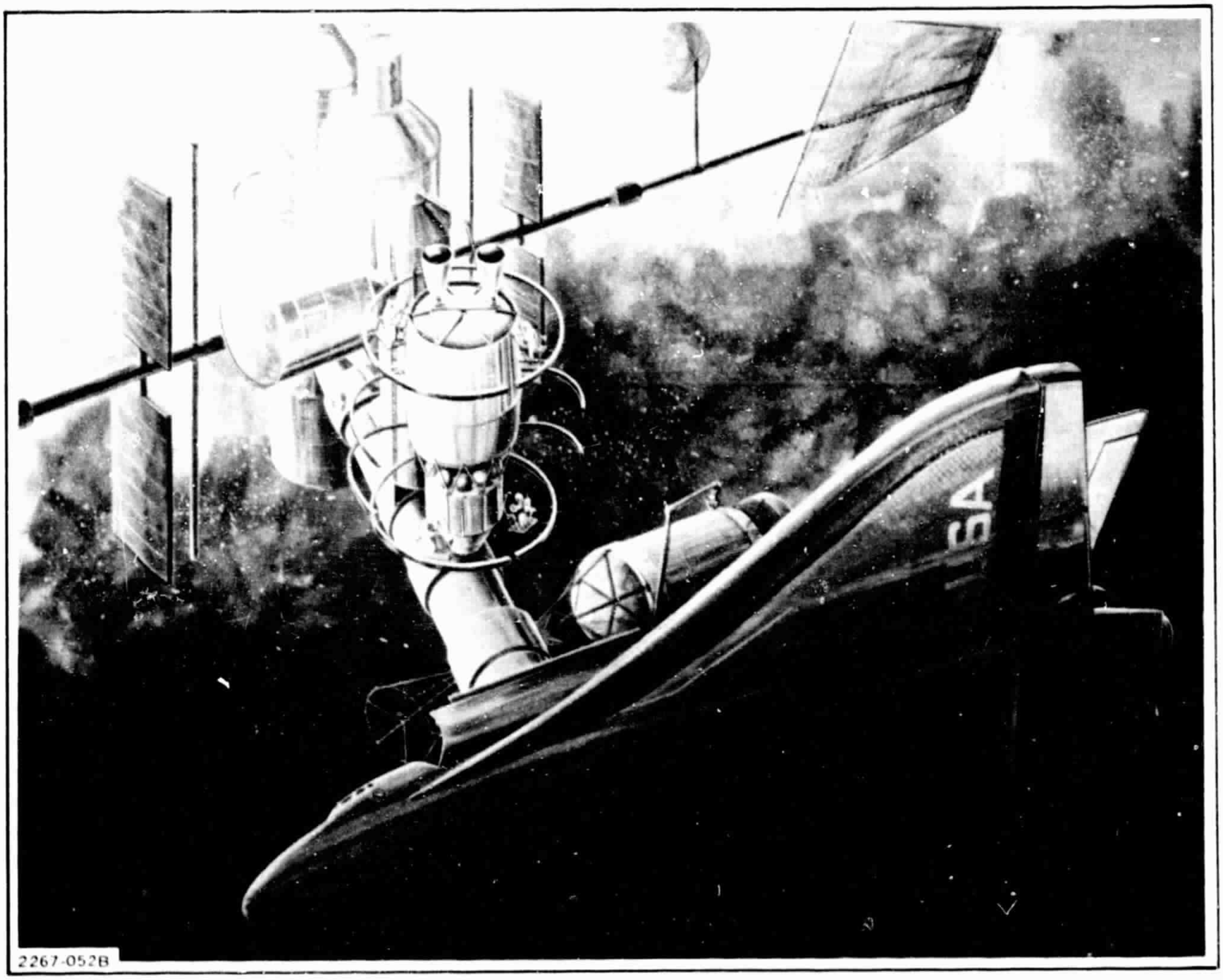

Fig. 4.14 SOC MOTV Turnaround Facility

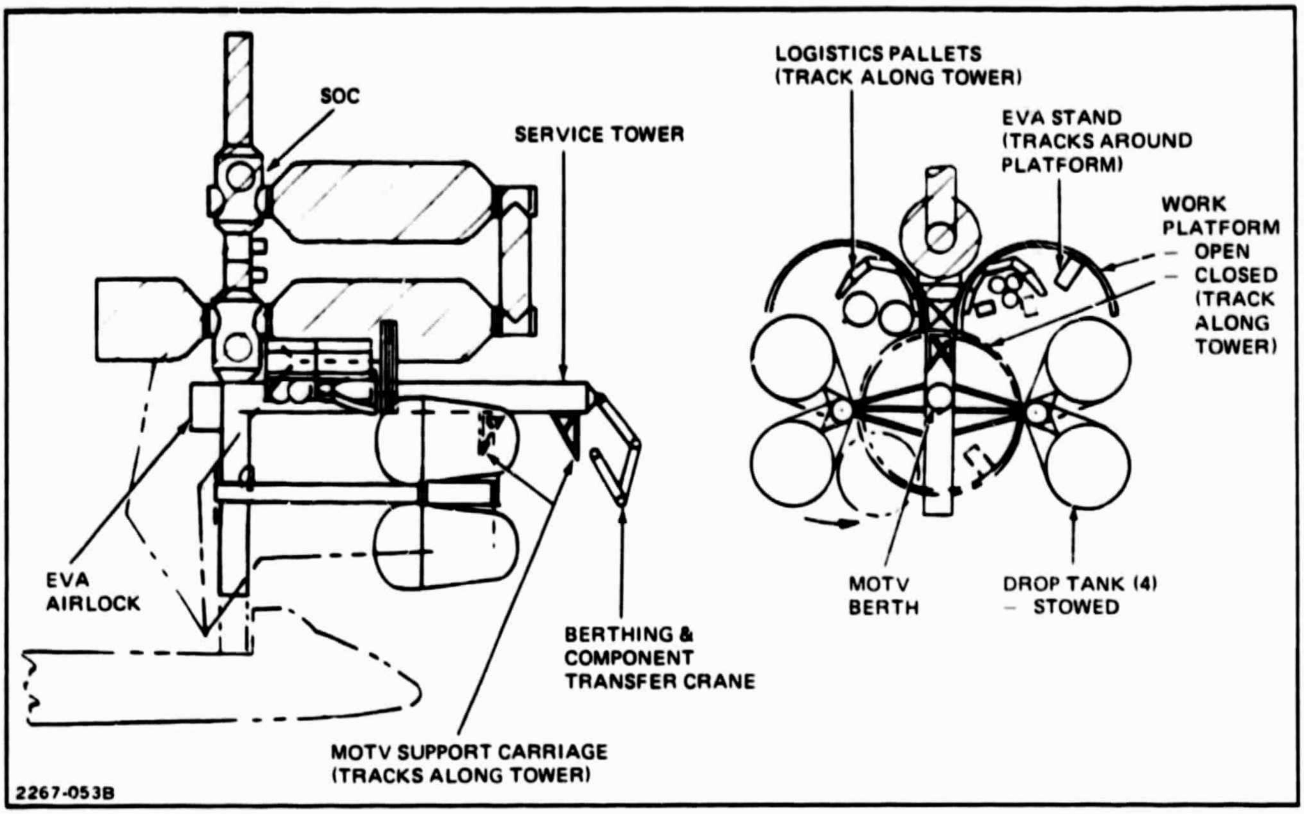

Fig. 4.15 MOTV Service Facility at SOC – EVA Servicing

the Shuttle while the MOTV is away on a mission, stowed clear of the work zone, then swung into mating position when required.

To perform tasks identified in the paragraph 4-4, 'shirtsleeve' scenarios, Fig. 4.16 shows a facility where the turnaround crew work in a pressurizable hangar. It is similar in layout to the facility for EVA servicing except for the hangar. Logistics are now contained in a pressurized module which is docked to the hangar. Work platforms no longer run up the service tower; they are located inside the hangar.

4.4.2 Baseline Support Equipment Requirements

Figures 4.17 and ·19 provide baseline support equipment for the recommended ground and SOC turnaround mix illustrated in Fig. 4.1.

Figure 4.17 shows the type of transportation, mechanical and fluid, that would be required to support the proposed SOC/GND mix of maintenance activities recommended. It shows a significant drop in the use of transportation and mechanical equipment required at SOC. The reduction in this type of equipment is possible because of the reduction in handling and other mechanical activity in SOC, plus the incorporation of SOC facility capability for related functions.

Figure 4.18 illustrates the kind of avionics support equipment required to support the proposed SOC/GND activities. The significant reduction in SOC equipment is based on the absence of detailed calibrations and performance tests conducted at SOC, these would be accomplished only on the ground, and the assumption that the vehicle Operational Flight Instruamentation System (OFIS) can check the health and status of all subsystems and identify inoperable LRUs.

4.4.3 Baseline Manpower Support Requirements

Tables 4.13 and 4.14 provide a baseline estimate of the ground and SOC manpower required to support the type of maintenance activities conducted at each facility. The ground crew would work on a two shift basis during overhaul. The SOC crew would work a single shift for post flight and periodic maintenance.

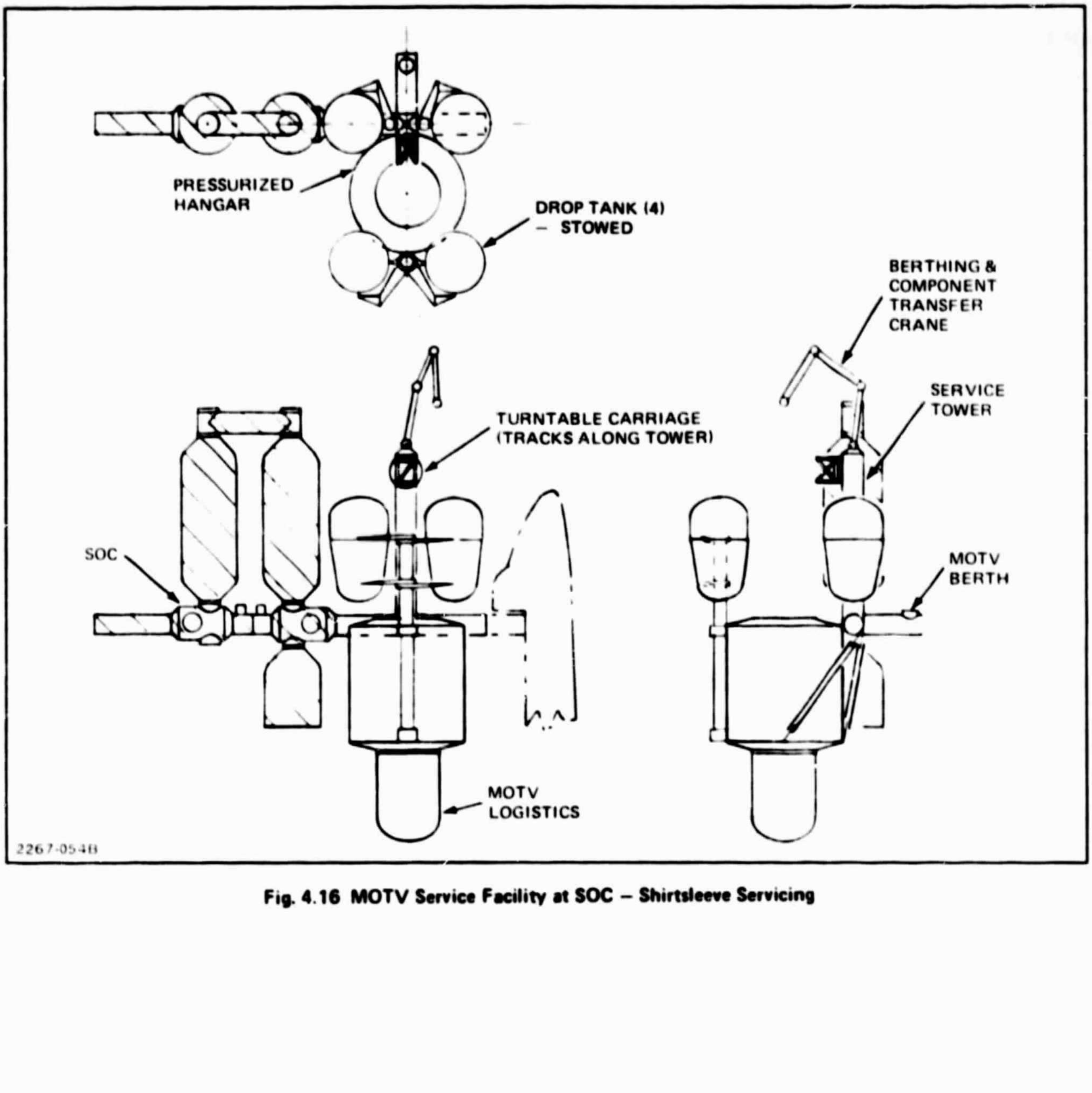

Fig. 4.16 MOTV Service Facility at SOC – Shirtsleeve Servicing

SUPPORT EQUIPMENT	GND	SOC
● TRANSPORTATION		
1) DROP TANK TRANSPORTERS (2)	X	
2) DROP TANK ENVIRONMENTAL COVERS (2)	X	
3) DROP TANK SHIPPING CONTAINERS (2)	X	
4) TRANSPORTATION TIEDOWN SET	X	
5) TRANSPORTER COOLING & PRESS. UNIT (3)	X	
6) CORE MODULE TRANSPORTER	X	
7) CORE MODULE ENVIRONMENTAL COVER	X	
8) CORE MODULE SHIPPING CONTAINER	X	
● MECHANICAL	X	
1) MOTV & INDEXED TURNTABLE		X
2) MOTV, PROP CORE, CREW MOD & TNK HANDLG. FIXTURE	X	X
3) CREW COMPARTMENT SLING	X	X
4) DROP TANK/CORE MODULE SLING SET	X	
5) DROP TANK SUPPORT RINGS (2)	X	X
6) WORKSTANDS – DROP TANK/CORE CREW MODULE	X	X
7) ENGINE DOLLY (2)	X	
8) ENGINE INSTALLATION TOOLS	X	
9) MODULE INSTALLATION FIXTURES (4)	X	
10) INTEGRATED ASSEMBLY WORKSTAND	X	
11) CORE MODULE SUPPORT RING	X	X
12) ENGINE THROAT PLUGS (2)	X	
13) PYRO SIMULATOR SET (1)	X	X
14) SOLAR ARRAY INSTALLATION TOOL	X	
15) SOLAR ARRAY DEPLOYMENT FIXTURE	X	
16) LRU SOC REPLACEMENT TOOLS		X
17) INSPECTION TOOLS	X	X

FLUID SUPPORT EQUIPMENT	GND	SOC
1) CABIN AIR SUPPLY UNIT (800 + 800 = 1600 x 35)	X	X
2) COOLING UNIT	X	X
3) CABIN LEAK TEST UNIT	X	X
4) ECLSS CHECKOUT CART (1100 + 1000)	X	X
5) GOX SERVICE UNIT	X	X
6) GN_2 SERVICE UNIT	X	X
7) N_2 PURGE SYSTEM	X	X
8) CYRO SYSTEMS C/O UNIT	X	
9) WATER STORAGE & TRANSFER UNIT	X	X
10) GOX SYSTEM VACUUM PUMP	X	X
11) WATER SYSTEM VACUUM PUMP	X	X
12) LEAK DETECTOR CART	X	X
13) PROPULSION SYSTEM C/O UNIT	X	X
14) HELIUM PRESSURIZATION UNIT	X	X
15) PURGE & DRYING CART	X	X
16) FUEL CELL VACUUM PUMP	X	X
17) FUEL CELL SERVICING UNIT	X	X
18) WASTE MGMT SYST SERVICING UNIT	X	X
19) Q.D./FILTER SET	X	X

2267-055B

Fig. 4.17 Transportation, Mechanical, Fluids Transportation Support Equipment Reqmts – Gnd & SOC Turnaround

SUPPORT EQUIPMENT	GROUND BASED	SOC
1) CAUTION & WARNING ELECTRONIC ASSEMBLY STIMULI GENERATOR	X	
2) RENDEZVOUS RADAR TEST BENCH	X	X
3) ATTITUDE CONTROL & DETERMINATION TEST STATION	X	
4) COMMUNICATION CHECKOUT & MAINTENANCE TEST STATION	X	
5) AUDIO CENTER TEST STATION	X	
6) DISPLAY & CONTROL CONSOLE	X	
7) PULSE CODE MODULATION & TIMING EQUIPMENT	X	
8) INSTRUMENTATION STIMULI GENERATOR	X	X
9) S/C STATUS ACQUISITION SYSTEM	X	
10) TV SYSTEM TEST SET	X	
11) S-BAND UPLINK AND DOWNLINK TEST SET	X	X
12) S BAND, X BAND, KU BAND ANTENNA MAINT TEST STATION	X	
13) DISPLAYS & CONTROL MAINTENANCE TEST STATION	X	
14) PRN RANGING TEST SET	X	
15) X BAND DOWNLINK DATA TEST SET	X	
16) DC TRANSIENT VOLTAGE POWER SUPPLY	X	
17) CONSTANT CURRENT BATTERY CHARGER	X	
18) INVERTER SIMULATOR	X	
19) ELECTRICAL LOAD SIMULATOR	X	
20) VEHICLE GROUND POWER SUPPLY	X	X
21) BATTERY MAINTENANCE TEST STATION	X	
22) ENVIRONMENTAL CONTROL SYSTEM TEST STATION	X	X
23) REACTION CONTROL S/S CONTROL STATION	X	
24) HELIUM PRESSURIZATION CONTROL UNIT	X	X
25) RCS PRESSURIZATION CONTROL STATION	X	
26) RCS FIRING CONTROL STATION	X	
27) MAIN PROPULSION ELECTRICAL TEST SET	X	X
28) DIAGNOSTIC AUTOMATED TEST COMPUTER		
29) DIAGNOSTIC COMPUTER DISPLAY		
30) COMPUTER KEYBOARD CALL UP		
31) POWER SOURCES SIMULATOR		
32) BATTERY CHECKOUT TEST DIAGNOSTIC STATION		

2267-056B

Fig. 4.18 Avionics Support Equipment Reqmts – Gnd & SOC Turnaround

TABLE 4.13 GROUND OVERHAUL MAINTENANCE MANPOWER REQUIRED

ACTIVITY AREA	MAINT PREPS	MAINTENANCE	INTEGRATE	PREP FOR MOVE
INSIDE CABIN	(2) 1 TECH, 1 ENG.	(2) TECH, 1 ENG.	(1) ENG.	(2) TECHS
OUTSIDE CABIN	(2) TECHS	(2) TECHS		(2) TECHS
AROUND INTERSTAGE	(1) TECH	(2) TECHS		(1) TECH
AROUND CORE	(2) TECHS	(2) TECHS		(2) TECHS
LPS (CONSOLE)		(2) SYS ENG.		
MAINT ANALYSIS CNTR		(4) SUBSYSTEM SPECIALIST		
GSE	(2) TECHS	(2) TECHS		(2) TECHS
DROP TANKS			(2) TECHS	
QC	(1)	(2)	(1)	(1)
MAINT DIRECTOR		(1)		
CRANE OPERATOR			(1)	
PHOTOGRAPHER		(1)		
PEAK MANPOWER TOTALS	10	20	4	10

2267-069B

TABLE 4.14 SOC POST FLIGHT AND PERIODIC MAINTENANCE MANPOWER REQUIRED

LOCATION \ ACTIVITY	MAINT PREP	MAINTENANCE	ASS'BLY & REFUEL	FINAL MISSION PREPS
@ SOC				
INSIDE CABIN	1	1	1	2*
OUTSIDE EVA	2	2	2	
ON GND DIRECT SUPPORT				
LPS CONSOLE		1	1	
SYSTEMS SPECIALIST	1	1	1	1
ON GND ON CALL		PROP, AVIONICS, ENGINE, & LOGISTICS SPECIALISTS	PROP SPECIALIST	
TOTALS DIRECT				
SOC PERSONNEL	3	3	3	0
GND PERSONNEL	1	1	1	1

*MOTV CREW MEN

2267-070B